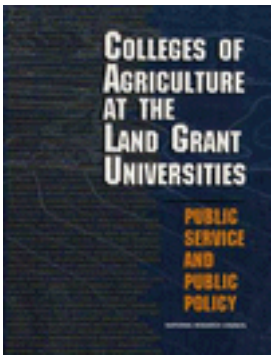

Colleges of Agriculture at the Land Grant Universities: Public Service and Public Policy

Committee on the Future of the Colleges of Agriculture in the Land Grant University System, National Research Council

ISBN: 0-309-58893-6, 140 pages, 8.5 x 11, (1996)

Colleges of Agriculture at the Land Grant Universities

Public Service and Public Policy

Committee on the Future of the Colleges of Agriculture in the Land Grant University System
Board on Agriculture
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1996

NATIONAL ACADEMY PRESS 2101 Constitution Avenue, NW Washington, DC 20418

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This study was supported by the Cooperative State Research, Education, and Extension Service of the U.S. Department of Agriculture, under Agreement No. 93-COOP-2-8575 and by the W. K. Kellogg Endowment Fund of the National Academy of Sciences and the Institute of Medicine. The Economic Research Service of the U.S. Department of Agriculture also provided support. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authoring committee and do not necessarily reflect the views of the sponsors.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is interim president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chairman and interim vice chairman, respectively, of the National Research Council.

Library of Congress Cataloging-in-Publication Data

Colleges of agriculture at the land grant universities : public service and public policy / Committee on the Future of Land Grant Colleges of Agriculture, Board on Agriculture, National Research Council.

p. cm.

Includes bibliographical references (p.) and index.

ISBN 0-309-05433-8 (alk. paper)

1. Agricultural colleges—United States. 2. Agricultural education—United States. 3. State universities and colleges—United States. I. National Research Council (U.S.). Committee on the Future of Land Grant Colleges of Agriculture.

S533.C695 1996

630'.71'173—dc20 96-26964

CIP

Printed in the United States of America

Committee On The Future Of The Colleges Of Agriculture In The Land Grant University System

ANTHONY S. EARL, *Chair,* Quarles and Brady Law Firm, Madison, Wisconsin
R. LEE BALDWIN, University of California, Davis
JOHN C. GORDON, Yale University
GORDON E. GUYER, State of Michigan Department of Agriculture
FRED HARRISON, JR., Fort Valley State College
EDWARD A. HILER, Texas A&M University
MARLYN JORGENSEN, Jorg-Anna Farms, Garrison, Iowa
DARYL B. LUND, Cornell University
THOMAS F. MALONE, The Sigma Xi Center, Research Triangle Park, North Carolina
MORTIMER H. NEUFVILLE, University of Maryland, Eastern Shore
ELIZABETH D. OWENS, ISK Biosciences Corporation, Mentor, Ohio
C. ALAN PETTIBONE, Washington State University
ALLEN ROSENFELD, Public Voice for Food and Health Policy, Washington, D.C.
CHARLES SAUL, Agway, Inc., Syracuse, New York
G. EDWARD SCHUH, University of Minnesota
GEORGE E. SEIDEL, JR., Colorado State University
JO ANN DOKE SMITH, Smith Associates, Irving, Texas
KATHERINE R. SMITH, Henry A. Wallace Institute for Alternative Agriculture
JAMES WYNGAARDEN, Duke University
ELISABETH A. ZINSER, University of Kentucky
JAMES J. ZUICHES, Washington State University

Staff

NICOLE BALLENGER, *Project Director*
DIBY KOUADIO, *Research Associate*[*]
JANET OVERTON, *Editor*
VIOLA HOREK, *Project Assistant*

[*] Through August 1995.

Board On Agriculture

Staff

[*] Through December 1995.
[†] Through April 1996.

Preface

The National Research Council's Committee on the Future of the Colleges of Agriculture in the Land Grant University System was convened in November 1993. The committee was charged with assessing the adaptation of the land grant colleges of agriculture to the public's changing needs and priorities and with recommending public policy and institutional change that could enhance the colleges' role in serving the national interest. The committee was composed of participants in the land grant system—administrators and faculty with teaching, research, and extension expertise—and representatives of public interest groups, state government, agribusiness, and the nonagricultural science community. Members of the committee come from all parts of the country and are diverse in terms of gender, age, experience, and ethnicity; thus the committee's deliberations reflect a variety of viewpoints.

This publication is the second of two volumes by the committee. The first publication, *Colleges of Agriculture at the Land Grant Universities: A Profile,* released in September 1995, was designed to lay an empirical base for the committee's deliberations and to contribute to public understanding and discussion of the college of agriculture system. The *Profile* report described the national network of colleges of agriculture and its operating environment—the U.S. food and agricultural system—yesterday and today. It compiled public data and information about the colleges' three main responsibilities—teaching students, conducting research, and extending knowledge and research findings to off-campus customers—and about federal policy for agricultural science and education. This second and final publication presents the committee's conclusions and recommendations for how the land grant college of agriculture system as a whole can be strengthened and best prepared for the future.

In the course of its deliberations, the committee acknowledged the diversity within the land grant college system and that it would not be possible to collect all the data or conduct the analyses that would lead to a credible evaluation of the content and quality of the many diverse programs and curricula. Thus, an assessment of strengths and weakness of individual college's teaching, research, and extension programs was not within the scope of the committee's work. The committee took instead a broad view. It focused its assessments on

- the changing economic and social context for the colleges' programs;
- the contemporary national interest in the land grant system in general, and in food and agricultural system science and education in particular;
- the federal role in supporting food and agricultural system science and education;
- recommendations for federal policy in keeping with the contemporary federal role; and
- identifying institutional innovations on the land grant campus that the committee believes will well serve the colleges—and the nation—today and into the future.

The committee approached the study in three phases. During the first phase, the committee collected, reviewed, and assessed public data and information about the colleges of agriculture and their operating environment and solicited the expert opinions of observers of and participants in the land grant system. The committee reviewed the historical background and early context of the land grant system, tracked its legislative history, and discussed the changes in U.S. society and the economy since the colleges' early years. On the basis of their review, the committee evaluated public data related to academic programs, research, and extension—for example, trends in student enrollments, demographics, and fields of study, federal funds for agricultural research, the changing mechanisms by which research funds are allocated, and how sources of funding differ across institutions. The evolving emphases of agricultural research and extension programs were also evaluated.

During the second phase, in the spring of 1995, committee members held public forums in five states—Connecticut, Missouri, New Mexico, North Carolina, and South Dakota. A forum had been scheduled in California also; however, because of the simultaneous scheduling of activities involving the U.S. Secretary of Agriculture, the committee received, instead, written public comment from the state's citizens. The goal of the forums was to broaden each committee member's personal experience with and exposure to a variety of land grant college campuses through up-close examination of the interface between college activities and public needs in five differing state and university environments. The information generated by the forums was inherently anecdotal, but it enriched and complemented the empirical portrait constructed more systematically through the use of quantitative indicators such as those published in the *Profile* report. Additionally, many of the examples of college programs and activities presented in this final report were identified during these state visits or through contact with the land grant colleges in those states.

The committee greatly appreciated the participation in the forums of more than 500 people and the written input from more than 50 Californians. In each state the forums drew significant attendance—college faculty and administrators, extension staff, farmers and ranchers, and representatives of commodity groups and agricultural industry. Although their numbers were fewer, attenders also included representatives of rural life and development programs, low-income and ethnic minority groups, food distribution networks, health care agencies, and youth and education programs. A number of representatives of state legislatures and a range of state agencies also attended or took time to meet with committee members.

Although the forums were an important and valued learning experience for all committee members, the committee recognized that the small number of forums in relation to the number of colleges of agriculture, coupled with the impossibility of guaranteeing attendance (because of timing, distance, and resources) by the full spectrum of stakeholder groups, would preclude basing its recommendations directly or solely on comments and discussion at the forums. The committee believes, however, that it is on solid ground in its conclusion that the participating colleges are acknowledging and attempting to confront challenges posed by changing times and state economies and it commends them for that effort.

The challenges differ in their particulars from state to state. In Connecticut the

college of agriculture assists farmers in meeting the environmental demands of a highly urbanized state and provides analytical and educational support for nutrition information programs in urban and low-income communities. In New Mexico, where there is a large base of support composed of farm and ranch clientele, the college of agriculture has established an environmental sciences program and a popular hospitality and tourism services program that reflects the growing role of tourism in the state economy.

The third phase of the study began in July 1995; from then through January 1996, the committee synthesized and integrated information from the first two phases and engaged in the deliberative process that resulted in this report.

The structure of this report, for simplicity, parallels the colleges' three functions—teaching, research, and extension. The committee felt strongly, however, that the land grant system's hallmark has been its historical commitment to an integrated three-part mission and that it is the relationship of the three functions to one another that unites science and education in service to the public. One of the main themes of Chapter 2, which presents a set of overarching themes, is the need to reinvigorate the tripartite mission; specific public policy measures are therefore proposed to strengthen the integration of teaching, research, and extension activities. Other crosscutting themes found in Chapter 2 are

- the need to develop and expand research programs and academic curricula that reflect an expanded view of the contemporary food and agricultural system;
- the possibilities for a new geography for the national college system that can enhance efficiency and enlarge the scope and relevance of programs; and
- a discussion of guiding principles for the use of public, especially federal, resources to fund food and agricultural system science and education.

Chapter 3 turns to the colleges' earliest responsibility: to teach. It affirms the strong national interest in educating students in food and agricultural sciences but also discusses the dynamism of the educational needs of the food and agricultural system and the challenges posed for the colleges. The chapter explores some innovative academic program areas in which the committee believes the colleges of agriculture show or have the potential to show considerable distinction. A key theme of the chapter is the valuable role that land grant colleges still play in assuring access to higher education, particularly for students in rural areas, but the focus is on the continuing challenges the colleges face in attracting and retaining students of diverse backgrounds and in enhancing the image of agricultural fields of study.

The focus of Chapter 4 is the research function. The case is made for why the food and agricultural system needs continuing advances in fundamental research, in research that integrates the findings of multiple disciplines, in research that applies the finding of "integrative" research to important issues and problems, and in research dissemination. The case is built for federal support of food and agricultural system research across the research continuum and particularly at the integrative stage. The chapter explores the merits of alternative mechanisms for funding food and agricultural system research, an issue of considerable importance in an era of constraints on public research funds and dynamism in the system's science base.

Chapter 5 turns to the third leg of the tripartite mission. Extension has in ways been the most dynamic of the land grant activities, as it has diversified it programs in response to the changing needs of local communities and followed its local funding base into urban and suburban settings. Extension may also face the greatest challenges, as it updates its delivery technologies, rethinks its delivery points, evaluates its role in serving both farm and nonfarm clients vis-à-vis private advisors and consultants, and builds the knowledge base for its programs. The chapter addresses the continuing national interest in a public extension service as well as the possibilities for public extension to take greater advantage of market opportunities and private financing.

In stepping back from the many specific and technical issues examined, the

committee's overriding sentiment is that the land grant system's greatest strength is its commitment to access to knowledge by all. The value to society of the realization of this commitment simply cannot be emphasized enough. Committee member Tom Malone captured the committee's sentiment well with these thoughts:

> Land grant colleges of agriculture can contribute effectively to the pursuit of a new vision for society. That vision is a society in which basic human needs and an equitable share of life's aspirations and wants can be met by successive generations while maintaining in perpetuity a healthy, physically attractive, and biologically productive environment. The successful pursuit of this vision requires vigorous development of the continuum of knowledge that embraces the discovery, integration, dissemination, and application of an understanding of the nature and the interaction of matter, living organisms, energy, information, and human behavior. The tradition of teaching, research, and extension at land grant colleges of agriculture is a superb institutional base upon which to erect this structure of knowledge.

The committee also concluded, as the 20 recommendations in this report attest, that there are areas where change is necessary to enhance the colleges' future prospects. The colleges must reach out to new clientele and implement priorities that reflect the complex needs of the 21st century's food and agricultural system. They must reexamine their partnerships with each other, the federal government, traditional and nontraditional clientele, and other units of the university. They must simultaneously respond to the opportunities posed by the dynamism in science and adapt to challenges posed by today's federal funding environment.

Anthony S. Earl, *Chair*

Committee on the Future of the Colleges of Agriculture in the Land Grant University System

Acknowledgements

We gratefully acknowledge the great many people who assisted in the development of this report by participating in the regional forums during the spring of 1995. The input we received from the spectrum of participants in the land grant college system was an important factor in shaping the views and recommendations of this committee. We also gratefully acknowledge those who took time from their busy schedules to attend various committee meetings. We offer thanks to the following individuals who served as invited speakers* at various committee meetings to share the wealth of their expertise and experience:

Julian Alston, University of California
Edward Barlow, Creating the Future
Sister Thomas Moore Bertels, Silver Lake College, Wisconsin
John Bottum, USDA Cooperative State Research, Education, and Extension Service
Rep. George Brown, Jr. (D/California)
David Call, Cornell University
Emery Castle, Oregon State University
Mary Clutter, National Science Foundation
Kenneth Deavers, USDA Economic Research Service
William DeLauder, Delaware State University
Ken Farrell, University of California
Richard Foster, W. K. Kellogg Foundation
David Goodstein, California Institute of Technology
Ted Hullar, University of California, Davis
Patrick Jordan, USDA Cooperative State Research, Education, and Extension Service
Joe Kunsman, National Association of State Universities and Land Grant Colleges
Peter Magrath, National Association of State Universities and Land Grant Colleges
Larry McCray, National Academy of Sciences, Policy Division
Per Pinstrup-Andersen, International Food Policy Research Institute
Carl Pray, Rutgers—The State University of New Jersey

* Note: Speakers affiliations are those they had at the time of their presentation.

ACKNOWLEDGEMENTS x

Contents

EXECUTIVE SUMMARY 1
The Colleges' Contemporary Context 2
Major Conclusions and Recommendations 3
Summary 11

1 INTRODUCTION 13
Uniqueness of the Land Grant College of Agriculture System 13
The Changing Context of the LGCA System and the New National Interest 14
Key Issues for the Federal Sector 18

2 A LAND GRANT SYSTEM FOR TOMORROW: OVERARCHING THEMES AND RECOMMENDATIONS 21
An Expanded and Inclusive View of the Modern Food and Agricultural System 21
A New Geography and New Partnerships 30
Renewing the Tripartite Mission: Integrating Teaching, Research, and Extension 37
Accountability and Principles for the Use of Public Funds 41

3 TEACHING 46
The National Interest in Food and Agricultural System Education 46
The Federal Role 50
Characteristics of Students, Faculty, and Academic Programs 53
Opportunities for Distinction 62
Summary and Recommendations 67

4 RESEARCH 69
The National Interest 69
Structure and Performance of the Current Land Grant Research System 73
Conclusions 85

5 EXTENSION 87
The National Interest in Public Access to Food and Agricultural Knowledge and Research 88
The Federal Role 90
Extension's Role in the Modern Context 92
Allocating Federal Extension Funds 102
Summary and Conclusions 103

REFERENCES 105

ABOUT THE AUTHORS 111

INDEX 117

Tables And Figures

Tables

2-1 Planning or Advisory Body Priorities for Food and Agricultural System Research and Education, 1994 27
3-1 Tuition and Fees at 1862 Institutions, 1992–1994 49
3-2 Tuition and Fees at 1890 Institutions, 1992–1994 50
3-3 Graduate Record Examination: Average of Verbal, Quantitative, and Analytical Scores, 1991–1994 54
4-1 Federal Agency Research and Development Support, 1994 74

Figures

2-1 Justifying federal support of agricultural research 44
3-1 The nature of scholarship 59
4-1 The research continuum 72

Box Titles

Recommendations for the Future of the Land Grant Colleges of Agriculture 4
LGCAs: Named for the Year of Their Mandate 15
Technological Change and the Development of U.S. Agriculture 16
Industrialization of U.S. Agriculture 24
USDA's Current Research Information System for Food and Agricultural Research 26
Distance Education 35
A Short Course by Satellite 36
Intramural Structural Issues 37
The Role of Students in Research 40
A Formal Mechanism for Integrating Teaching, Research, and Extension 42
The Land Grant Colleges' Early Years 47
The Demand for College Graduates in Food and Agriculture-Related Fields 51
USDA-Administered Higher Education Grants 52
GIS Training at Lincoln University 55
South Dakota State University's "2+2+2" Program with Reservation High Schools and Tribal Colleges 57
Curriculum Revitalization Projects 61
"Transdisciplinary" Teaching at the University of Maryland 63
Teaching Science through Agriculture 66
The Cascade of Knowledge 71
A Profile of Two State Agricultural Experiment Station Researchers 76
Competitive Grants 78
Checkoff Funds 82
How Is University Extension Different from Cooperative Extension? 88
The Original Role for Federal Government 90
Origins of Cooperative Extension 93
Independent Crop Consultants 97
Multidisciplinary Foundation of Food and Nutritional Sciences 101

Colleges of Agriculture at the Land Grant Universities

Executive Summary

In 1862, almost 50 percent of all U.S. residents lived on farms, which employed almost 60 percent of the labor force. The business of the day was agriculture, and the land grant college of agriculture (LGCA) system was mandated

> … to teach such branches of learning as are related to agriculture and the mechanical arts … in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life (1862 Morrill Act).

Initiated in 1862 with the passage of the first Morrill Act, and expanded in 1890 with the passage of the second Morrill Act, the LGCA system was the first embodiment of a post-Civil War national philosophy about higher education—the concept of higher education of a practical nature for citizens of ordinary means.

The 1862 Morrill Act produced land grant colleges in every state and territory and the District of Columbia. The 59 resulting colleges (including 3 within the University of California system and 6 in U.S. territories) are known as the 1862 colleges or "1862s." The second Morrill Act, which mandated access to African-Americans, gave rise to a set of historically Black colleges located in southern states and known as the 1890 colleges or "1890s." There are 17 1890 institutions—16 public state colleges and Tuskegee University.

As full-fledged universities grew up around the original colleges, the LGCAs continued to have a unique relationship with the public and the federal government—one that has lasted more than 130 years and has some distinctive features. In initiating this study, the National Research Council (NRC) felt that an assessment was needed of whether these long-standing institutional arrangements continue to work to the advantage of the nation and, indeed, to the advantage of the LGCA system.

The two Morrill acts and two subsequent pieces of land grant legislation, the 1887 Hatch Act and the 1914 Smith-Lever Act, together endowed the LGCAs with a three-part mission of teaching, research, and extension. Extension was designed to link the colleges' academic and research programs to societal needs through a public service function that includes extended education and technology transfer. Motivated by the desire to draw each state and territory into supporting science and education related to agriculture, land grant legislation created a federal-state partnership in agricultural research and technology

transfer. The partners have traditionally been the U.S. Department of Agriculture (USDA), at the federal level, and every state and territory, through their land grant colleges and associated state agricultural experiment stations and extension services, at the state and local levels. Cementing the partnership is a financial arrangement: each state and territory receives federal funding through USDA for its agricultural research and extension programs, contingent on each state and territory matching these federal funds.[1] These institutional funds for LGCAs' research and extension programs are administered by USDA and allocated based on formulas. The major components of the formulas are the percentages of the nation's rural and farm populations located in each state and territory.

Recently, about 30 percent of all research expenditures by LGCAs' state agricultural experiment stations derived from federal funds; state appropriations and private funds accounted for 51 percent and 19 percent, respectively. Of the 30 percent of expenditures supported by federal funds, about one-third came from formula funds, 10 percent from competitive research grants administered by USDA and specifically designated for food and agricultural system research, 13 percent from congressionally designated special grants, and 44 percent from non-USDA agencies including the National Institutes of Health, the U.S. Agency for International Development, the National Science Foundation, and others.

Land grant colleges' extension services are supported by federal, state, local government and private funds. Recently, state appropriations contributed 47 percent, federal funds contributed 29 percent, and local government and private support accounted for 24 percent. The federal funds are drawn from USDA-administered formula funds (69 percent), congressionally designated funds (28 percent), and other federal sources (3 percent). Federal funding for teaching programs in food and agricultural sciences has been minimal in relation to support for research and extension (USDA-administered programs total $18 million); a formula such as those used to fund research and extension has never been adopted, nor is it proposed here.

THE COLLEGES' CONTEMPORARY CONTEXT

Since the colleges' early years, the nation has experienced dramatic changes in the business of farming. First, in good part because of the colleges' contributions to agricultural knowledge and farm technology, farming is today an industry based on science and technology. The productivity of farm labor has increased almost sevenfold since 1948 as a result of the development of modern farm technology, the use of more capital relative to labor, and improvements in the quality of inputs and managerial practices.

Second, the profile of a farm has changed dramatically since the LGCA system's early years. Family farms still account for the majority of farms in the United States; however, the contemporary family farm is often a complex business entity, and family farms range in size from small-scale specialty farms to very large-scale, commercial organizations. Farming has also become a highly concentrated industry, thus a relatively small share of all farms produce a significantly larger share of all farm output. Associated with the great size disparity among U.S. farms is the fact that there are farmers of significantly different economic means, educational backgrounds, research capacities, and information needs.

Third, some segments of the U.S. food and agricultural sector are increasingly industrialized. In other words, farming, processing, and marketing are increasingly coordinated activities controlled through ownership or contractual arrangements by a single firm or "integrator." In such operations, the seed, animals, or feed used for production may be owned by the integrating firm, which has a technical and professional staff that provides context-specific information to contractors based on proprietary data and research.

[1] As discussed in Chapters 4 and 5, state governments are not required to match federal funds designated for research and extension programs at 1890 institutions. The matching requirement for the funds to 1890s was omitted by legislators because they feared that states would not agree to provide the matching funds and, thus, federal funds to those institutions would be lost.

These developments are requiring LGCAs in some parts of the country to rethink their partnerships with some farm and ranch client groups.

Along with changes in the farm sector, the national interest in the performance of the food and agricultural system, of which farming is one component, has evolved over the decades to reflect a wider array of public expectations. The modern food and agricultural system encompasses primary production, processing, marketing, and retailing—consumer-oriented activities that now provide 18 percent of U.S. employment, 16 percent of "value added" to domestic production, and substantial contributions to the nation's export earnings. The food and agricultural system includes, as well, the interaction of these economic activities with natural resources and the environment, human communities and their well-being, and consumer health, safety, and ethics—interactions often difficult to evaluate in economic terms but clearly valued by contemporary society. Expanding global population, tightening global resource constraints, and environmental quality and food safety concerns combine to underscore the need for continued improvement in the productivity and sustainability of the food and agricultural system and the quality and safety of its products.

MAJOR CONCLUSIONS AND RECOMMENDATIONS

The committee assessed the adaptations of each of the three functions of the LGCAs—teaching, research, and extension—to the colleges' contemporary environment and the U.S. public's changing needs and priorities. A national science and education infrastructure that underpins continued advances in performance of the food and agricultural system, and federal support of that infrastructure, remain squarely in the national interest. The committee identified, however, four principal areas for change. Specifically, within the LGCA system there is

1. the need for greater relevance and accessibility through programs that embody an expanded view of the modern food and agricultural system and through inclusion of a wider array of students, faculty, and clientele of diverse backgrounds and perspectives;
2. the need to remove historic barriers and, indeed, encourage research, teaching, and extension collaborations that cross disciplines, institutions, and states; to encourage faculty and student exchanges; and to make all programs in the system accessible to as wide a variety of stakeholders as possible—that is, there is a firm need to create a "new geography" that cannot be confined to a locality;
3. the need for stronger linkages among the equally important functions of teaching, research, and extension as well as the need to reinvigorate the colleges' role as models of the land grant concept and philosophy; and finally,
4. the need for heightened accountability and quality through competitive processes for funding, guiding principles for the use of public (especially federal) resources, and more regular and critical evaluations of publicly funded programs.

Twenty recommendations were developed to enhance the ability of the LGCAs to respond to the challenges posed by these themes (see Recommendations Table).

Relevance and Accessibility of the LGCA System

LGCAs should garner effective input from a wide variety of stakeholders; receipt of federal (USDA-administered) funds—both formula funds and competitive grants—should be contingent on the demonstration of such input (Chapter 2, Recommendation 1). LGCAs have a responsibility, based on their philosophical roots and legislative mandate, to be relevant and accessible to the general public and particularly to citizens of ordinary means. However, many of today's food and agricultural system beneficiaries, such as urban and suburban residents and environmentalists, have little knowledge of or connection to many of the LGCAs. These connections should be enhanced to ensure that resource allocation at LGCAs increasingly reflects the broad and diverse national interest in the food and agricultural system, an outcome crucial to extending the colleges' relevance into the 21st century.

RECOMMENDATIONS FOR THE FUTURE OF THE LAND GRANT COLLEGES OF AGRICULTURE

1 Receipt by LGCAs of USDA-administered research and extension funds—including formula funds and competitive grants—should be contingent on their ability to demonstrate that a wide variety of stakeholders have effective input into a systematic prioritization (no less often than biennially) of research, extension, and joint research-extension issues, that specifies areas of increased and decreased emphasis. Further, LGCAs must demonstrate that a wide variety of stakeholders are consulted in resource allocation decision making processes.
Located in Chapter 2, "Overarching Themes and Recommendations"

2 In light of the changing structure of agriculture and the importance of diverse participants in production agriculture, the LGCA system should critically assess the needs of all producer population groups, develop priorities and targeted programs for each, and adjust technology transfer and information delivery modes appropriately.
Located in Chapter 2, "Overarching Themes and Recommendations"

3 Federal programs and policies should enhance the LGCA system's efforts to realize organizational efficiencies and synergies that broaden and deepen the system's expertise and expand access and relevancy. Significant shares (25 percent or more) of total current USDA-administered extramural funds—including formula funds and competitive grants—for food and agricultural research, teaching, and extension should provide incentives for

- regional centers, consortia, programs, and projects that effectively integrate and mobilize multistate and multi-institutional (including 1862, 1890, and 1994 colleges') resources; and
- distance learning and other technologies that expand access, broaden clientele, and enhance multi-institution collaboration in teaching, research, and extension.

Located in Chapter 2, "Overarching Themes and Recommendations"

4 The LGCA system and the federal government must revitalize the linkages among teaching, research, and extension. To further this goal, the committee recommends the following.

- Federal formula funding for research and extension should be combined into a single allocation to LGCAs for food and agricultural system research and extension, requiring that the use of these combined funds reflect a coordinated effort to link university research and extension in the national interest. (It should be strongly underscored that the intent of this recommendation is not to reduce the importance or destroy the integrity of one function or the other but to encourage their integration.)
- It should be required that one-half of the formula funds for research and extension at each institution be directed to fund programs, projects, and activities that integrate teaching, research, and extension, with a special emphasis on inter- and multidisciplinary programs and projects, and the engagement of students on research teams and in extension programs as interns and aides.

Located in Chapter 2, "Overarching Themes and Recommendations"

5 Regular and critical evaluations of federally funded research and extension programs should assess the congruence between such programs to which federal funds are devoted and the provision or enhancement of public goods of regional and national significance.
Located in Chapter 2, "Overarching Themes and Recommendations"

6 The bridging programs among 1862s, 1890s, and 1994s deserve special emphasis from federal funding programs, such as federal challenge grants, including evaluation of their effectiveness as models for expanding access and diversity in the food and agricultural sciences. The federal government should also become an active promoter of the use of articulation agreements among institutions within and across states to facilitate student exchanges and transfers, and encourage collaborative internship programs among institutions in the LGCA system.
Located in Chapter 2, "Overarching Themes and Recommendations"

7 The colleges of agriculture should require students to take at least one internship from a wide range of creative, mentored internship opportunities representing the diverse career settings for which graduates in food and agricultural sciences are prepared.
Located in Chapter 3, "Teaching"

8 The federal government should expand competitive challenge grants to creative teachers and teaching teams to develop innovative multidisciplinary and systems-based course material and curricula.
Located in Chapter 3, "Teaching"

9 The federal government should increase competitive funding of food and agricultural research projects. The funding level for competitive grants should be no less than the $500 million authorized by Congress for the National Initiative for Research in Agriculture, Food, and the Environment (NRI). Additionally, the share of total federal research support awarded competitively to projects and individuals (including teams) on the basis of peer-reviewed merit should be increased. Recognizing fiscal constraints, options for increasing the share include (a) directing funds to research from other USDA budget categories, particularly as a means of reinvesting savings on agricultural subsidies; (b) transferring to competitive grants programs a portion of the funds currently distributed to experiment stations by formula and special grants; and (c) drawing on USDA intramural noncompetitive research funding. Consistent with Recommendation 1, a two-tier review system similar to that of NIH, should be used at the federal level to guarantee that public benefits as well as scientific merit guide the selection of research proposals.
Located in Chapter 4, "Research"

10 USDA should continue its role in enhancing participation and success in competitive grant programs by all institutions in order to build human capital nationwide in food and agricultural research. For example, it should (a) continue to designate 10 percent of the enlarged competitive grants pool for institutions in USDA-EPSCoR states; (b) allocate 5 percent of competitive grants for 1890 institutions, while maintaining capacity building grants; and (c) streamline the federal competitive grants application process without sacrificing accountability or the adequacy of information on which to judge scientific merit.
Located in Chapter 4, "Research"

11 A new formula by which food and agricultural research funds are allocated within the land grant system should be designed and implemented to accurately reflect the full range of food and agricultural research beneficiaries.
Located in Chapter 4, "Research"

12 The federal government should require that states match formula research funds going to 1890 institutions in the same manner as is required for 1862 institutions.
Located in Chapter 4, "Research"

13 Data on extension projects and programs, goals, and outcomes should be compiled and organized more systematically to enhance their usefulness to extension administrators and clientele and to aid in analyses of the returns on public investments in farm and nonfarm extension programs.
Located in Chapter 5, "Extension"

14 The federal government should require that states match formula extension funds going to 1890 institutions in the same manner as required for 1862s.
Located in Chapter 5, "Extension"

15 Extension programs must be underpinned by an academic research base in the land grant university. Consequently, the committee strongly encourages land grant universities to embrace the mandate of outreach and extension and to ensure that the entire university is accessible and responsive as the research base for farm and nonfarm extension programs. To accomplish this, administrative structures, incentives, and reward recognition must be generated within the university to promote the commitment and involvement of faculty, staff, and administrators across the university to actively participate in outreach, extension, and public service.
Located in Chapter 5, "Extension"

16 Federal agencies (operating under the auspices of a Cabinet-level task force) should identify appropriate opportunities to link programs at the Health and Human Services, Commerce, and other departments to USDA-based extension, especially in the delivery of services to nonfarm clientele.
Located in Chapter 5, "Extension"

17 The research base for extension's nonfarm programs, such as community and economic development, human development, and public policy, should be enhanced by strengthening the land grant universities' applied research capacity in economics, sociology, public health, and related disciplines and their applications to extension programs.
Located in Chapter 5, "Extension"

18 New and innovative approaches to augment extension financing should be pursued, as appropriate, taking into account implications for access to extension by limited-resource farmers and other limited-resource clientele groups.
Located in Chapter 5, "Extension"

19 A new formula by which base food and agricultural extension funds are allocated within the land grant system should be designed and implemented to accurately reflect the full range of food and agricultural extension service beneficiaries.
Located in Chapter 5, "Extension"

20 All national extension initiatives should be available on a competitive basis to land grant and non-land grant institutions. Consistent with the committee's prior recommendations (Recommendations 3, 4, 15, and 17), these competitive grants should provide incentives for
Located in Chapter 5, "Extension"

- multistate, multi-institution, or regional extension programs;
- new and innovative approaches to the delivery of extension services, particularly where access can be expanded significantly and benefits shared across political boundaries;
- programs that significantly improve the science base for extension programs, such as those dealing with human nutrition education and social science issues; and
- programs that enhance the public service component of academic programs.

Federal funding programs should augment efforts of LGCAs to bridge and link academic programs of 1862 colleges, 1890 colleges, and 1994 colleges (Chapter 2, Recommendation 6). LGCAs have recognized for some time the need to enhance diversity among their student populations and, through that process, the faculty, scientists, managers, technicians, and policy makers in food and agricultural fields. The historically Black 1890 colleges have played a significant role in training minority-group students in the food and agricultural sciences and related disciplines. Twenty-nine Native American colleges joined the land grant system through federal legislation in 1994; these "1994" colleges provide another potential avenue for increasing representation by a more diverse citizenry within food and agricultural science. Unfortunately, the 1890s (and 1994s, which are mostly 2-year institutions) offer few graduate-level training opportunities. Bridging agreements that facilitate the automatic transfer of students from one institution to another, once specified academic requirements have been met, could prove to be a useful mechanism for creating these opportunities. Enhancing such formal linkages among 1862, 1890, and 1994 land grant institutions may be key to advancing the role of minority-group professionals in scientific research and education, as well as in the management, technological, and policy making arenas of agriculture.

Two additional recommendations targeted the relevance and accessibility of LGCA programs:

- In response to the increasingly complex and diverse structure of U.S. agriculture, LGCAs must recognize the diversity of producer groups and target priorities, programs, and delivery mechanisms accordingly (Chapter 2, Recommendation 2).
- To enhance the role of 1890 colleges as providers of access to underrepresented producers and consumers, the federal government should require that states match federal formula funds for research and extension for 1890 colleges in the same manner as required for 1862 colleges (Chapter 4, Recommendation 12, and Chapter 5, Recommendation 14).

A New Geography for the LGCA System

Federal programs and policies should be structured so that significant shares (e.g., 25 percent or more) of current USDA-administered extramural funds—both formula funds and competitive grants—for teaching, research, and extension be used to provide incentives for programs and projects that effectively integrate and mobilize multistate and multi-institutional resources (Chapter 2, Recommendation 3). Today there are many reasons for bringing organizational

efficiencies to the LGCA system through creating a new geography based on multistate, multi-institutional, and multidisciplinary collaborations and partnerships. The case for a new geography rests on a number of findings:

- States are often not the best unit of organization or operation for food and agricultural research issues or extension programs. (Improving water quality, for example, may require the coordinated approach of several states sharing a watershed.)
- In the face of fiscal constraints, a broadened agenda for food and agricultural education, research, and extension requires more efficient use of resources within the national LGCA system.
- Smaller, less well-supported LGCAs may have to develop partnerships with other institutions to survive.
- Interconnectedness with other institutions and other parts of the country, through modern technologies such as videos, telecommunications, and the Internet, as well as transportation networks, offers broader exposure of students and faculty alike to diverse ideas, perspectives, values, and cultures.

Mechanisms other than the current federal policy of allocating 25 percent of formula research funds to regional projects must be found. The current approach is inflexible with respect to which institutions receive the funding because it is allocated by formula rather than based on the merit of the regional projects, largely ad hoc rather than linked to a formal prioritization process, and not successful in generating genuine multi-institutional, multidisciplinary, and regionally based approaches.

Competitive challenge grants should reward teachers and teaching teams that develop innovative multidisciplinary and systems-based course material and curricula (Chapter 3, Recommendation 8). LGCAs and federal grants programs must foster partnerships among faculty from different disciplines to build the knowledge base for sustainable food and agricultural production systems. Discoveries in the different disciplines (genetics, plant physiology, crop breeding, animal science, and economics, for example) realize their greatest potential value when related to one another and applied to real-world needs through *integrative* research. For this reason, the committee also strongly endorses special divisions of competitive grants programs for multidisciplinary research projects.

Linkages should be developed among programs at non-USDA agencies and USDA-based extension programs (Chapter 5, Recommendation 16). The colleges of agriculture and the USDA must develop linkages and partnerships with both university units and government agencies outside the LGCA system. Extension programs, for example, now encompass many nonfarm issues such as nutrition education and economic, community, and human resource development. These programs rely—actually or ideally—on a science and policy base often found, at least in part, outside the college of agriculture. These programs may also have a more synergistic effect in combination with public service programs administered by federal agencies other than USDA.

Reinvigorating the Tripartite Mission

Federal formula funds for research and extension should be combined into a single allocation; 50 percent of combined funds should be used to fund programs, projects, and activities that integrate teaching, research, and extension or the work of multiple disciplinarians (Chapter 2, Recommendation 4). LGCA administrations, faculty appointments, budgets, and federal land grant legislation are structured along the lines of teaching, research, and extension. Although it is the historical commitment to its three-part mission that has distinguished the LGCAs, the separate administrative and funding structures too often hinder integration of the three functions and their programs. The different statuses implicitly, if not explicitly, assigned to each function by the university community contributes to the separateness. Furthermore, the primary subject-matter focuses of LGCA undergraduates (agribusiness and agricultural economics and natural resource fields), of college research faculty (animal and plant sciences), and of extension staff (nutrition education; youth,

family, community, and leadership development; and other social science issues) have diverged significantly over the years; thus limiting the ready-made opportunities to integrate academic, research, and extension programs. Even with the acknowledged commitment to a balanced and integrated approach, teaching, research, and extension linkages can and should be improved.

Federal incentives and signals are important but not sufficient. The entire university should be accessible and responsive as the research base for extension programs (Chapter 5, Recommendation 15). The integration of teaching, research, and extension is valued for several reasons. Research-extension linkages, when they work well, spawn a two-way flow of insights and information that enhances the relevancy of research and uses research findings where they are most valuable to the public. Strong research-extension linkages help ensure that outreach programs reflect the most up-to-date scientific knowledge. The integration of teaching, research, and extension is of special value to students because it offers an academic experience that involves students in both the process of scientific discovery (as members of research teams) and public service (as extension interns and aides).

Two additional recommendations were designed to revitalize the linkages among teaching, research, and extension in the food and agricultural sciences.

1. *Students should be required to serve an internship in any of a wide range of settings representing diverse career opportunities (Chapter 3, Recommendation 7).*
2. *To strengthen the research base for extension programs, the applied research capacity in economics, sociology, public health, and related disciplines should be improved as should their applications to extension programs (Chapter 5, Recommendation 17).*

Federal Funding: Levels and Guiding Principles

The federal partner should increase its use of competitive research grants to fund projects and individuals on the basis of merit as determined by peer review (Chapter 4, Recommendation 9). Federal research and development (R&D) funds totaled $69 billion in 1994. A little more than 2 percent ($1.5 billion) funded R&D conducted or administered by USDA. Of the USDA portion, approximately 30 percent ($400 million)—or 0.6 percent of all federal R&D—funded agricultural research conducted outside of USDA (most often at land grant colleges and universities). Of these USDA-administered extramural funds, approximately 55 percent were allocated to land grant colleges according to a formula; approximately 25 percent was in the form of competitive grants accessible to all researchers in and outside of land grant colleges; and the remainder was in the form of congressionally designated grants to institutions for specific programs.

These numbers were factors in two conclusions drawn by the committee. First, federal support of research designated for food and agricultural system issues and problems is indeed modest in light of (a) the heightened national interest in the performance of the food and agricultural system, (b) the evidence from the economics literature describing high social rates of return on public investments in agricultural research (from 30 to 50 percent), and (c) the total federal investment in R&D. Second, USDA-administered research funding differs from other R&D funding in the much smaller percentage allocated to individuals and projects on the basis of merit review and competition because of (a) the relatively large share of agricultural research conducted intramurally by USDA agencies and (b) the use of formula funds and congressionally designated grants in allocating extramural funds to institutions. Consequently, the committee strongly supports full funding of the $500 million competitive grants program for food and agricultural system research that was detailed in the 1989 NRC report entitled *Investing in Research: A Proposal to Strengthen the Agricultural Food and Environmental System*. Merit-based, peer-reviewed research by scientists within and outside the land grant colleges and their research experiment stations is essential to discover and advance the fundamental knowledge needed to enhance productivity and sustainability of the world's food and agricultural system. There is also a continued valuable role for formula funded research

at land grant colleges based on the special needs outlined in this report and the unique opportunities formula funds provide. However, formula-funded research like competitively funded research must undergo reviews for scientific merit, relevance, and accountability.

Arguments can be made for and against both formula-based funding to institutions and competitive grants to individuals and projects—each comes with benefits and costs. However, some of the early reasons for formula funding of state experiment stations, such as the need to draw each state and territory into agricultural research and the site-specific nature of agricultural research, carry less weight today. Today most states provide far more financial support than is required to match the federal dollars; and many types of food and agricultural research, such as nutrition, food safety, and biotechnology, have little or no location specificity. Other arguments for formula funds, such as the ways they can be used to link research to extension programs that respond to local, state, and regional needs, and their support for certain applied research projects that require long-term continuity (such as maintenance research required to renovate or replace deteriorations in past gains in crop productivity), remain quite compelling. Despite its uniqueness, agricultural research needs to enhance quality, accountability, and equity through greater use of competitive allocation mechanisms.

In constructing its recommendation for increased funding of USDA's competitive grant programs and an increase in the total share of federal research support that is awarded competitively to projects and individuals (including teams) on the basis of peer-reviewed merit, the committee was mindful of budget realities. It accepted and even offered options for funding trade-offs, including:

1. directing funds to research from other USDA budget categories, particularly as a means of reinvesting savings on agricultural subsidies;
2. transferring to competitive grants programs *a portion of* the funds currently distributed to experiment station by formula and special grants; and
3. drawing on USDA intramural noncompetitive research funding.

Furthermore, the committee challenges the LGCAs to generate resources needed to address a broader array of public issues through greater efficiency of organization and through realizing the potential for new relationships between the public and private sectors.

The formula by which food and agricultural research and extension funds are allocated should be redesigned so as to reflect the full range of food and agricultural research and extension beneficiaries (Chapter 4, Recommendation 11, and Chapter 5, Recommendation 19). The formula by which federal formula funds are allocated to the land grant colleges is outdated in relation to modern food and agricultural system issues and constituencies. These formulas were generated in an era when a much higher percentage of the nation's population was rural and farm based, and the nation's agricultural interests were dominated by concerns with domestic crop production and food security. Today, many issues of concern to the U.S. public, such as diet and health, food safety, and families and youth at risk, are not specific to farm production regions, suggesting the need to rethink formulas for both research and extension programs.

The congruence of federally funded programs with well-justified guidelines for federal funding should be reviewed critically and regularly. (Chapter 2, Recommendation 5). Public accountability in the use of federal funds for food and agricultural system research and extension would be enhanced by periodic evaluation of whether guidelines for public funding are being followed. These guidelines are particularly important because the incentives for the private sector to conduct food and agricultural research and extension have increased, while public R&D resources have seen relatively little growth. Federal support is justified and needed for food and agricultural research and extension activities that address national needs and priorities and provide *public goods* —that is, goods that benefit society

but that are not supplied in optimal amounts by a competitive market. Public goods in the context of the food and agricultural system include

- fundamental knowledge (which may be embodied in agronomic practices);
- protection or enhancement of environmental quality;
- knowledge about food and product safety risks and protection from undue risk;
- improved human health through diet and nutrition;
- protection against genuine national food security risks; and
- knowledge essential to the accomplishment of national goals such as social equity, economic efficiency, and informed public policy making.

Federal support is particularly well justified for those research and extension activities that produce public goods that cross political (state) boundaries or for which political boundaries do not apply; hence the committee's support for multi-institutional and regional programs and projects.

New approaches to augmenting extension financing should be pursued (Chapter 5, Recommendation 18). In many other countries, what in the United States is considered public extension service has been substantially privatized. In the United States, the land grant system's extension services are increasingly being offered also by the private sector through, for example, private crop consultants and technicians employed by integrator firms. Despite the growing role for private actors in disseminating agricultural information and technology, the committee concludes that public extension remains in the national interest because it helps ensure that research translates into practical applications with broad-based benefits; that information is widely accessible, accurate, and science-based; and that the problems and needs of all groups—not just those who can afford to pay—are relayed to research scientists and administrators. Nonetheless, extension can today pursue new and innovative approaches to the delivery of services to expand access and share benefits across political boundaries; explore multi-institutional and regional arrangements to increase efficiency and maintain service levels; improve linkages to university research and academic programs to strengthen the science base (for its nonfarm programs in particular); and better target limited resource clientele with publicly funded services. In addition, the federal government should increase the use of competitive grants and merit-based review to allocate federal dollars appropriated for innovative extension initiatives (Chapter 5, Recommendation 20).

Federal Policy versus Institutional Leadership

Many of the committee's recommendations address federal policy, particularly federal funding. This is because the allocation of federal funds sends important signals and provides important incentives to institutions and individuals. Nonetheless, the future of the LGCAs is most likely to be shaped by the colleges themselves as they adapt their programs to contemporary food and agricultural system issues.

There are many areas in which the colleges, working within the university, can take the lead. For example, colleges of agriculture have revised tenure and promotion guidelines that reward scholarship in many diverse forms, and that recognize the potential for scholarship in the teaching and extension missions. Many colleges have taken important steps in curriculum innovation to enhance the roles of environmental sciences, nutritional and food sciences, international studies, and courses that integrate basic and social sciences with food and agricultural issues and applications.

SUMMARY

The land grant system has served the nation well, but changes are needed that reflect modern realities, challenges, and opportunities. In particular, the system must increase it relevance to contemporary food and agriculture system issues and concerns; reinvigorate its commitment to the linkages among teaching, research, and public service; organize its programs and projects more efficiently and more in keeping with the regional and

multistate requirements of many modern food and agriculture system problems; and enhance its accountability to the public.

Federal funding has an important role in promoting innovation. Federal formula funds should be administered more efficiently (as one budget category rather than two); used more creatively to "jump start" programs and projects that more effectively integrate research, extension, and teaching, and the work of multiple disciplines; and their allocation among states and regions needs to be rethought, including improving the allocation and effectiveness of the 25 percent of formula research funds designated for regional projects. Federal formula funds have a particularly important role in supporting the programs of the historically Black 1890 colleges. In the interest of equity and the importance of the clientele served by historically Black 1890 colleges, states should be required to match federal formula funds to these institutions (as they are required to do in the case of 1862s).

The role of competitive grants and merit review in food and agricultural system research and extension should be enhanced. Competitive grant program administrators should also draw upon the NIH model to develop a two-tier review system, and they should continue to strive to provide incentives for inter- and multidisciplinary research in food and agriculture. Competitive grant program design should encourage participation and potential for success by smaller research institutions and 1890s (which currently rely heavily on formula funds) in order to sustain and build human capital in food and agricultural research nationwide; and multistate and multi-institutional programs and projects that reflect the appropriate geographical configuration of many contemporary food and agricultural system problems.

Their historical commitment to public service distinguishes the LGCAs. The committee's deliberations led to the conclusion that the tripartite tradition of teaching, research, and extension at the land grant colleges is a unique institutional base on which to erect the structure of knowledge that can assure a socially, economically, and ecologically sustainable food and agricultural system. Some components of colleges of agriculture could be appropriate models for the other colleges and programs of the land grant universities as they seek to integrate their teaching, research, and outreach activities.

1

Introduction

The Board on Agriculture of the National Research Council (NRC) convened the Committee on the Future of the Colleges of Agriculture in the Land Grant University System in November 1993 to assess adaptations of the tripartite mission of teaching, research, and extension at land grant colleges of agriculture (LGCAs) to

- a changing client base for food and agricultural research and education,
- a reinvigorated science base for food and agriculture, and
- constrained public resources for science and education.

The committee was charged with recommending public policies and institutional innovations that could enhance the land grant colleges' role in serving the national interest. The committee's first report, *Colleges of Agriculture at the Land Grant Universities: A Profile* (National Research Council, 1995a) provides a great deal of background material about the LGCA system and U.S. agriculture. The *Profile* report is often cited in this report and is intended to be used as a companion document for the reader who seeks additional quantitative and descriptive detail.

The science and education agencies of the U.S. Department of Agriculture (USDA) were sponsors of this study, recognizing that this is a time of diverse and complex public issues and concerns regarding the food and agricultural system. Their leadership also recognized the value of an independent assessment of an institution born of federal legislation and supported largely by state and federal funds.

UNIQUENESS OF THE LAND GRANT COLLEGE OF AGRICULTURE SYSTEM

The LGCA system is a unique component of higher education in the United States. Initiated in 1862 with the passage of the first Morrill Act, the LGCAs were mandated to bring higher education of a practical nature to citizens of ordinary means. The LGCA commitment to higher education in service to the public was in sharp contrast to the orientation of most of the nation's academic institutions of the time (Meyer, 1993), which emphasized the study of philosophy, theology, law, medicine, and the classics. In 1862 almost 50 percent of all U.S. residents lived on farms, and almost 60 percent of the labor force worked on them (National Research Council, 1995a). The business of the day was

agriculture, and so the "leading object" of the new land grant colleges was "to teach such branches of learning as are related to agriculture and the mechanical arts … in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life" (1862 Morrill Act). The opening of land grant colleges during the latter half of the 19th century helped expand higher education opportunities into the western parts of the nation as the population also migrated westward.

Throughout their history, the land grant colleges of agriculture have had a unique relationship with the federal government and a special responsibility to the public. Three pieces of federal legislation—the first Morrill Act (1862), the Hatch Act (1887), and the Smith-Lever Act (1914)—endowed the colleges with a three-part mission of teaching, research, and extension. The third component of the mission—extension—links the LGCAs' programs to the needs of society at large through a service function that includes extending education and technology transfer to the public.

Federal legislation also spawned a federal-state partnership in agricultural science and education (with a local government component, as well, for extension). The traditional federal partner is the USDA, particularly its extra- and intramural science agencies. As described in the *Profile* report, the USDA agency that administers base funding and grants programs for extramural research, education, and extension is the Cooperative State Research, Education, and Extension Service (CSREES). [1] Each U.S. state and territorial government (through their land grant colleges and associated state agricultural experiment stations and extension services) is a partner at the state and territorial levels.

The partnership has a financial component: each state and territory receives federal funding through USDA for its agricultural research and extension if it matches these federal funds with its own resources. The federal-state partnership also entails a working relationship in identifying national issues and setting priorities in food and agricultural research and education, and in sharing responsibilities for the conduct of agricultural research and technology transfer.

A unique aspect of the LGCA system is that a portion of federal funding for agricultural research and extension is allocated to the colleges, through their associated state experiment stations and extension services, according to formulas.[2] The variable components of these formulas are the percentages of the nation's rural and farm populations located in each state and territory. Federal funding for research has been allocated by this formula since the 1935 Bankhead-Jones Act, and federal funding for extension has been allocated by formula since the 1914 Smith-Lever Act (National Research Council, 1995a).

In sum, the LGCA system has a distinctive history and is defined by some unique institutional arrangements. This report is oriented toward assessing how well these arrangements have continued to function in the context of changes in farming, in societal issues and concerns related to food and agriculture, in the science base for food and agriculture, and in the public funding environment.

THE CHANGING CONTEXT OF THE LGCA SYSTEM AND THE NEW NATIONAL INTEREST

Since the colleges' early years, and in good part because of the colleges' contributions to agricultural knowledge and farm productivity, the agricultural industry, nationwide, has undergone a transformation. The productivity of farm labor has increased almost sevenfold since 1948, and the productivity of all farm inputs together has almost tripled since 1948 as a result of the development of modern farm technology and improvements

[1] The main intramural science agency at USDA is the Agricultural Research Service. Intramural research is also conducted by the Economic Research Service and the Forest Service. Intramural research agencies have contracts and cooperative agreements with the land grant colleges, as well as other collaborative relationships.

[2] Until recently, LGCAs also received base institutional support, known as Morrill-Nelson grants, for their academic programs. Recently these funds were eliminated and a USDA-administered competitive grants program for curriculum and teaching innovation (challenge grants) was expanded. Unlike Morrill-Nelson funds, challenge grants are accessible to non-land grant faculty.

LGCAS: NAMED FOR THE YEAR OF THEIR MANDATE

The original Morrill Act (1862) mandated that colleges of agriculture b established in all U.S. states and territories and the District of Columbia, totaling 59 colleges as "1862s" (including three land grant campuses as part of the University of California system).

The second Morrill Act (1890) mandated a second set of land grant colleges in that it conditioned receipt of federal funds to land grant colleges on access to African-Americans. Thus, southern states initiated separate colleges for African-American students. Today there are 17 historically Black land grant colleges known as "1890s," which serve an increasingly diverse student population (Christy and Williamson, 1992; National Research Council 1995a). Over the years, 1890 institutions have become recipients of federal funding for land grant institutions; however, federal law does not require that states match federal funds to 1890s, whereas it does require that states match federal funds for 1862s.

In 1994, the Elementary and Secondary Education Reauthorization Act conferred land grant status on the 29 Native American Colleges that comprise the American Indian Higher Education Consortium. An endowment was authorized to fund these colleges as well as funds for the colleges' education and extension programs in agricultural and natural resources. Thus were born the "1994s."

Today the 1862s, 1890s, and 1994s constitute the 105 institutions that compose the land grant colleges of agriculture system

in the quality of inputs and managerial practices (Executive Office of the President, 1995). Public investments in agricultural science and technology have helped make farm labor more productive, farm output more stable and abundant, and farm commodities less costly to food processors and manufacturers—outcomes that have benefited not only the farm sector but also U.S. consumers and the U.S. economy generally.

Today farms are residences for less than 2 percent of all U.S. citizens and employ approximately 3 percent of the U.S. labor force, whereas 75 percent of U.S. citizens live in urban and suburban environments, and the vast majority do not work on farms. Nonetheless, the performance of the food and agricultural system, of which farming is one component, is extremely important to the U.S. economy, and indeed, to the world economy. Today's U.S. food and agricultural system encompasses food and fiber production, processing, marketing, and retailing—activities that provide 18 percent of U.S. employment, 16 percent of "value added" to domestic production, and significant and increasing amounts of foreign exchange through farm and food export earnings (National Research Council, 1995a).

The U.S. public is also increasingly concerned about how these primary production and processing activities interact with natural resources and the environment, rural communities, consumer health, safety, and ethics. The monetary value of environmental quality, the natural resource base, human health, and the quality of life are often difficult to measure but are clearly of value to society. Diet-related health; food safety; water and air quality; soil, water, and energy conservation; wildlife habitat; open space and the nation's landscape; and a "way of life" that is associated with the family farm and rural

TECHNOLOGICAL CHANGE AND THE DEVELOPMENT OF U.S. AGRICULTURE

The remarkable increases in agricultural productivity wrought by scientific discovery and agricultural technology development contributed importantly to the growth of the U.S. economy. Since more food and fiber could be produced using fewer of the nation's resources, other parts of the economy could grow more rapidly. And, since farm commodities could be produced at less cost, food and fiber products could be priced more reasonably and consumers had more remaining income to spend on other goods and services. These interrelationships continue to be important to sustaining global economic performance and to stimulating economic growth in developing countries.

The need for a science base to underpin the development of agricultural technology was already, by 1887, well recognized when the Hatch Act formally established the state agricultural experiment stations. Early on, the science of agriculture was influenced by both supply-side and demand-side factors. Supply-side factors included developments in fundamental science, such as those of the "father of organic chemistry," Justus von Liebig, to which agricultural scientists had access. Demand-side factors included the technical needs of the farmers, such as identifying the most suitable varieties and agronomic practices for growing small grains in the Plains States (Cochrane, 1979). Today's supply-side factors might be thought to be developments in biotechnology and genetic engineering, while demand-side factors include the needs of producers and a wide variety of food and agricultural system issues that concern a more affluent society.

Over the decades, economic forces have been among the strongest influences shaping the nature of agricultural innovations in both the private and public sectors. Economists use the "induced-innovation model" to explain the relation between economic conditions and the rate and direction of technological change. The model assumes that innovators, including farmers, scientists, and entrepreneurs, develop new technologies that conserve relatively expensive resources and use relatively less expensive ones. The induced-innovation model helps explain the surge in farm mechanization during manpower shortages that occurred during the Civil War and as the nation expanded westward between 1870 and 1900 (Cochrane, 1979). It also helps explain why yield-increasing technologies were developed and adopted on a significant scale after the close of land frontier in the early 20th century. Hayami and Ruttan (1985) apply the induced-innovation model to argue that declining real-energy prices (in relation to land and labor costs) induced the widespread adoption of petroleum-based fertilizers and chemicals.

As the U.S. economy grew and family incomes increased, consumer preferences became increasingly important in influencing the contributions of science to the food and agricultural system. Innovators have responded rapidly to many modern consumer demands that are reflected in the marketplace, such as preferences for a variety of convenient products with desirable sensory attributes. The induced-innovation model suggests, however, that other contemporary consumer concerns, such as environmental quality, food safety and nutrition, and other nonsensory food attributes, will be

undersupplied by technological development because their values are often not captured in market prices for farm products or inputs and so the signals to innovators are incomplete. For example, Ruttan (1971) explained why agricultural research would overemphasize technologies that use chemical inputs and underinvest in technologies that conserve them: the negative effects on society of agricultural chemical use are not reflected in costs of production borne by farmers or the market prices of farm products. The committee's discussion, throughout this report, of the need for public research and extension resources to enhance the provision of public goods—goods likely to be undersupplied by the private sector, such as fundamental knowledge, environmental quality, food safety, and social equity—is in keeping with this historical overview of the development of U.S. agriculture and the role of technological change and economic forces.

communities: these are all concerns of taxpayers who finance food and agricultural research, education, and extension. For example, the relationship between diet and human health is increasingly well documented. According to some research, improving dietary habits might prevent at least 20 percent of deaths annually from heart disease, cancer, stroke, and diabetes. Diet as well as other factors—including genetic predisposition—are related to hypertension, osteoporosis, and obesity, which affect productivity and life span (Frazao, 1995). The breadth of this set of issues, as well as the obvious relevance to all U.S. residents, means that the constituencies of the colleges of agriculture include those who live in urban and suburban communities as well as those who live on farms and in rural areas.

Continuing food security—that is, access to food at reasonable prices—for the nation and the world is also among national concerns as global population continues to expand and food production extends to environmentally sensitive and marginal lands. World population is expected to reach 7.4–8.4 billion in 2020 (United Nations, 1995). According to the International Food Policy Research Institute (IFPRI), crop yields are expected to increase at slower rates over the next 25 years than have been experienced during the past decade, assuming governments maintain their current (recently reduced) levels of support for agricultural research and infrastructure. IFPRI analyses indicate that further cuts in research and infrastructure investments, and in health, nutrition, and education programs, could result in increases in world food prices and in more malnutrition among children in developing countries (Rosegrant et al., 1995).[3]

In this highly interdependent global economy for food and agricultural products, developments in the U.S. agricultural sector have implications for economic growth, food security, and nutritional health in the rest of the world; and, conversely, developments on a global level are reflected in U.S. supermarkets and in our pocketbooks. Responding to these national and global issues and concerns requires scientific knowledge that spans and integrates the physical, biological, and social sciences.

Paralleling changes in society's interests in the food and agricultural system are major changes in the food and agricultural science base and science institutions. Genetic

[3] The IFPRI analysis (Rosegrant et al., 1995) is based on a population projection of 8 billion people in 2020. The United Nations projects a high of 8.392 billion and a low of 7.372 billion people for that year (United Nations, 1995).

engineering of plants and animals is dramatically changing food and agricultural science. Patent protection for genetically modified organisms is simultaneously increasing incentives for the private sector to engage in proprietary research in food, plant, and animal sciences. Although the *Profile* report notes that the real value of total USDA research agency appropriations increased less than 1 percent annually between 1980 and 1990 and only 2 percent annually between 1990 and 1993, the private sector's role has increased substantially. Currently the private sector's role is estimated to be larger than the public sector's role, and it has expanded significantly in areas, such as plant breeding, that were once almost entirely public responsibilities (Klotz et al., 1995). Additionally, the private sector's role in financing research conducted at the public land grant colleges has also increased in size and relative importance (National Research Council, 1995a), raising issues of how the public-private partnerships can evolve profitably and in keeping with the public service mandate of land grant institutions.

The farm production sector has itself changed dramatically since the LGCA system's early years. The sector has become highly concentrated, such that a small portion of all farms produce a majority of the farm output entering major commercial channels. In addition to the great size disparity among U.S. farms is the fact that U.S. farmers span the income scale from high income and highly capitalized to low-income and limited resource. These different farm populations may have very different expectations and needs as regards the college of agriculture and very different abilities to pay for research findings and extension services.

Industrial agriculture, characterized by vertical ownership (that is, control by a single corporate entity) of farming, processing, and marketing activities, is becoming more important. It is a trend that is challenging the traditional role of the public land grant colleges in serving independent farmers and ranchers whose agricultural operations are too small to conduct their own research or their own market analysis. At the same time, parts of the country are seeing new participants in farming, or old participants engaged in a new kind of farming, such as small-scale units oriented toward suburban and urban niche markets for fresh produce and other family farm products. There is also growing acceptance nationwide of alternative farming production technologies[4]; and there is a growing recognition of the need for education and research that expand and improve technological options for sustainable production systems—systems that enhance the compatibility of farm profitability, environmental quality, and human communities (Anderson, 1995).

KEY ISSUES FOR THE FEDERAL SECTOR

As discussed above, the LGCAs are in part a federal responsibility. A long list of federal legislation following the Morrill, Hatch, and Smith-Lever Acts expanded funding to the college system, revamped funding mechanisms, expanded or refined provisions for the use of federal funds, and even added institutions to the system. For example, the 1925 Purnell Act emphasized the role of the LGCAs in improving rural life. The 1946 Research and Marketing Act revised the formula for allocating formula funds for research (also known as Hatch funds). The 1977 National Agricultural Research, Extension, and Teaching Policy Act (the 1977 farm bill) instituted formula funds for research at 1890

[4] According to *Alternative Agriculture* (National Research Council, 1989a), alternative agriculture is not a single system of farming practices. It includes a spectrum of farming systems, ranging from organic systems that attempt to use no purchased synthetic chemical inputs, to those involving the prudent use of pesticides or antibiotics to control specific pests or diseases. Alternative farming encompasses, but is not limited to, farming systems known as biological, low-input, organic, regenerative, or sustainable. It includes a range of practices such as integrated pest management (IPM); low-intensity animal production systems; crop rotations designed to reduce pest damage, improve crop health, decrease soil erosion, and, in the case of legumes, fix nitrogen in the soil; and tillage and planting practices that reduce soil erosion and help control weeds. Alternative farmers incorporate these and other practices into their farming operations.

colleges, new formula-based funds for animal health research, and a new competitive grants program to be administered by the USDA but open to all scientists inside and outside of the land grant system. The 1990 Food, Agriculture, Conservation, and Trade Act (the 1990 farm bill) expanded the 1977 competitive grants program by mandating the National Initiative for Research on Agriculture, Food, and Environment (known as the NRI).

Today, for many LGCAs, federal formula funds contribute a relatively small portion of their total financial base; the primary portion of the funding base is state support, but it also encompasses private funds and other federal grants funds (awarded by federal science agencies such as the National Science Foundation and the National Institutes of Health). In 1992, federal formula funds accounted for 10 percent of total research expenditure by state agricultural experiment stations, while state support accounted for 50 percent (National Research Council, 1995a). However, there are many land grant colleges for which these USDA-administered formula funds (which total about $500 million for both research and extension) remain a vital component of their funding base. Different approaches to federal funding could mean different futures for the diverse institutions within the LGCA system.

Among the important federal issues that helped focus the work of the committee and this report are the following:

- What is the contemporary and future national interest in a federally supported LGCA system?
- How should federal funds be allocated? By what mechanisms? To which institutions, programs, and projects?
- What are the implications for the use of public funds as regards the growing private sector role in food and agricultural research and extension? How do the public and private sectors complement each other in the national interest?
- How can limited federal funds be a catalyst for institutional innovation that responds to contemporary and future societal issues and realities?

Methodology Used to Develop This Study

The study was designed to have three stages. During the first, the committee collected, reviewed, and assessed public data and information about the LGCAs and their operating environment and solicited the expert opinions of observers of and participants in the land grant system. The committee reviewed the historical background and early context of the LGCA system, tracked its legislative history, and discussed the changes in U.S. society and the economy since the colleges' early years. Against this setting, the committee evaluated public data related to academic programs, research, and extension, such as trends in student enrollments, demographics, fields of study, federal funds for agricultural research, the changing mechanisms by which research funds are allocated and how sources of funding differ across institutions, and the evolving emphases of agricultural research and extension programs. Much of the data and background information collected by the committee was published in the interim report, *Colleges of Agriculture at the Land Grant Universities: A Profile* (National Research Council, 1995a). Developing the *Profile* report was a means of building a common base of understanding among committee members and of laying an empirical foundation for deliberations. The *Profile* report was published to make the data collected available and useful to the many who were interested in or already engaged in shaping the future of the land grant system.

The second stage of the study occurred in the spring of 1995, when committee members held public forums in five states—Connecticut, Missouri, New Mexico, North Carolina, and South Dakota. From California, where a forum was scheduled but canceled due to previously scheduled activities of the U.S. Secretary of Agriculture, written public comment was provided by would-be participants in the forum. The goal of the forums was an up-close examination of the interface between college activities and public needs

in five differing state and university environments. Each forum had three major sessions: one with members of external client groups, one with college administrators and staff, and one with representatives of state agencies and legislative offices. In Missouri and North Carolina, the committee visited with staff of both 1862 and 1890 institutions. The information generated by the forums was anecdotal (and representation of client groups at the forums was affected by travel time and costs and scheduling conflicts), but it enriched and tended to support the empirical portrait constructed more systematically through the use of quantitative indicators such as those published in the *Profile* report. Additionally, many of the examples of college programs and activities presented in this report were identified during these state visits or through contact with the land grant colleges in these states.

The third stage of the study began in July 1995 at the committee's fifth meeting. During July 1995 through January 1996, the committee synthesized and integrated information from the first two phases and engaged in the deliberative process that has resulted in this final report.

Organization of the Remainder of This Report

Separate pieces of federal land grant legislation address the land grant system's teaching, research, and extension responsibilities. College administrative structures and budgets, and faculty appointment types and responsibilities, are also divided along the lines of the three land grant functions. There are also distinct constituencies for the colleges' teaching, research, and extension programs. For these reasons, this report contains separate chapters that address each component of the colleges' three-part mission. However, many important issues—such as access to and relevancy of the LGCA system, the organization and efficiency of the LGCA system, the justification for federal funding of the system, and, indeed, the integration of the three functions as one mission—are relevant to all three activities. A set of these cross-cutting themes and issues is presented in Chapter 2. Discussion of these themes precedes individual treatment of the three-part mission, in Chapters 3 through 5, to emphasize the committee's view that the land grant system of tomorrow is one that will have renewed its historical commitment to service to the public through an integrated mission of teaching, research, and extension. Chapter 3 (Teaching) discusses student test scores, student-faculty contact and incentives to teach, and academic programs and curricula in which the committee believes the LGCAs have opportunities for distinction. Chapter 4 (Research) discusses why food and agricultural system research is needed across the research continuum, which encompasses fundamental, integrative, and adaptive research and dissemination of research, and federal research funding levels and mechanisms. Chapter 5 (Extension) addresses extension's role in serving urban and suburban, as well as farm and nonfarm rural clients, and new approaches to financing public extension.

2

A Land Grant System For Tomorrow: Overarching Themes and Recommendations

In the course of its deliberations, the committee recognized that a number of themes surfaced, often regardless of whether the focus of the discussion was teaching, research, or extension. These overarching themes and accompanying recommendations, which are grouped in this chapter, represent the committee's consensus on how the LGCA system as a whole can be strengthened and best prepared for the future.

Four overarching themes emerged:

1. the need for an expanded and inclusive view of the modern food and agricultural system;
2. the need for multistate, multi-institutional, and multidisciplinary collaborations and partnerships (that is, a "new geography" for the land grant system);
3. the need to reinvigorate the tripartite mission through the integration of teaching, research, and extension; and
4. the need for enhanced accountability and guiding principles for the use of public, especially federal, resources.

AN EXPANDED AND INCLUSIVE VIEW OF THE MODERN FOOD AND AGRICULTURAL SYSTEM

The committee believes that the national network of LGCAs must critically and continually assess its challenges and opportunities against an expanding and inclusive panorama of the modern food and agricultural system. An understanding of the complex needs and evolving characteristics of the food and agricultural system is a necessary condition for the continuing relevance of the land grant system, especially for its future as the major public repository of the food and agricultural system's knowledge base. An appreciation for the diversity of participants and stakeholders in the modern food and agricultural system is the basis for an institution that continues to be accessible to people and their practical needs. Relevancy and accessibility are at the heart of the land grant philosophy and mandate.

The modern U.S. food and agricultural system is large, complex, diverse, and dynamic. These characteristic are documented in the committee's first report, *Colleges of Agriculture at the Land Grant Universities: A Profile* (National Research Council, 1995a) and are thus only briefly recapped here.

Characteristics of the Food and Agricultural System

Consumer Driven

The U.S. food and agricultural system is increasingly driven by consumers' preferences and concerns, in keeping with its its role in a highly developed economy. Today these preferences and concerns encompass price, sensory attributes, nutrition, convenience, variety, food safety, diet-related health, cultural and ethnic preferences, and concerns regarding the methods of producing foods and raising animals and their impacts. Most of the economic value in the food and agricultural system is generated outside the farm gate as commodities are transformed for consumer markets through processing, manufacturing, and packaging and differentiated to meet specific consumer preferences. Additionally, farm production practices, the goals of plant and animal breeding, and the application of biotechnology to crops and livestock are themselves increasingly responsive to consumer preferences and concerns. Yet, at the same time that consumer-oriented markets are a driving force in the food and agricultural system, consumers themselves often have less (or asymmetric) information about the qualities and embodied attributes, particularly nonsensory attributes, of food and agricultural products than do manufacturers and suppliers. Incomplete or inaccurate information precludes consumers from always making well-informed changes in consumption patterns, thus market forces may not influence product and technology development in ways that best serve consumers' needs (see Box text, pp. 16–17). Although public policy includes labeling, food safety, and other production certification standards, the situation creates the need for public sector research.

Ecosystem Accountability

The food and agricultural system is increasingly asked to be accountable to an urban- and suburban-based public for its conservation of natural resources such as water, soil, rangeland, and fossil fuels and for protection of environmental amenities spanning open space, wildlife habitat, and water and air quality. Farmers are asked to be —and many want to be—effective natural resource stewards and ecosystem managers. They consequently face an increasingly complex policy and regulatory environment; they require new knowledge and expertise regarding management and technological alternatives that can help them manage pests and control disease, be profitable and competitive, and be accountable to public concerns.

Global Markets

The food and agricultural system is a global system. Significant shares of not only bulk commodities but also processed food and agricultural products enter global markets in search of new customers, creating jobs in export-oriented industries, and generating foreign exchange for the nation. Goods, capital, and technology flow readily across national boundaries expanding trade, foreign investment, and technological opportunities in the food and agricultural industry and contributing to global economic growth, while creating a more intensely competitive environment for producers, firms, and workers. A global system also means that U.S. consumers cannot be insulated from pressures on food and agricultural markets that might occur as world population continues to expand in the presence of constrained resources or unsustainable resource use. Thus both U.S. and non-U.S. consumers and producers share interests in science and research that continue to improve the efficiency of global markets and the sustainability of production systems.

Biotechnology's Role

Food and agricultural production is increasingly science based, and the food and agricultural system is increasingly able to capitalize on scientists' growing command of

the genetics of plants and livestock. This has important implications for the ability to adapt crop varieties and livestock to meet consumer demands for food attributes. It may also be an important means of reducing reliance on farm chemicals and thereby enhancing farm worker safety, food safety, and environmental quality. This new science has intellectual property protection in the form of patents and thus comes with new incentives for the private sector to engage in agricultural research and development. There is yet, however, no biotechnology "fix." The joint and profitable management of productive resources and public goods (such as air and water quality, natural habitat, and human health) requires tremendously sophisticated knowledge of biological and physical processes and systems, and the ability to integrate and base management decisions on large amounts of quantitative information (Lacy, 1993).

Economic Inequities

The food and agricultural system continues to be characterized by economic inequities. Despite enormous productivity and production abundance, the system still includes many individuals and families who have inadequate access to food and a substandard nutritional status. In fact, 1 in 10 U.S. citizens is a recipient of food stamps, and many who do not participate in the food stamp program do meet the qualifications (U.S. General Accounting Office, 1988). The food and agricultural system also includes many limited-resource farmers who confront poverty with few economic alternatives. Approximately 185,000 of the 2.1 million farm operators in the United States have been classified by USDA as "limited-opportunity farm-operator households"—that is, farm-operator households that have (a) farm sales less than $100,000, (b) farm assets less than $150,000, and (c) gross household income less than $20,000 (U.S. Department of Agriculture, Economic Research Service, 1996). Most of these households are located in the South, and the operators tend to be older and have less formal education than the majority of farm operators.

"The Farm": A Changing Perspective

The food and agricultural economy is highly concentrated. Economic concentration has long characterized food distribution and processing and the agricultural inputs sector. The primary production or farm sector has also become increasingly concentrated. The majority of farms are medium- and small-scale operations, but they produce a much smaller share of the agricultural output that enters commercial channels (and a majority of these farms rely significantly on off-farm sources of income); a much smaller number of very large farms produce most commercial output (National Research Council, 1995a). This is a trend that is unlikely to be reversed but that has nonetheless troubled U.S. society, which values its concept of the "family farm."

An emerging characteristic of the U.S. food and agricultural system is "industrialization." In the industrialized sector, farming, processing, and marketing activities are vertically integrated and may be components of a single corporate entity. Subcontractors are employed to manage, for example, the crop or livestock operation, while livestock and other assets are owned and much of the decision making is controlled by the firm acting as "integrator." The consumer-orientated food markets, the globalization of markets, and the new science base for agriculture (Paarlberg, 1995) have been factors in the increasing industrialization of agriculture. For example, introducing new varieties of fruits and vegetables, establishing brands, and contracting out with farmers are strategies adopted by biotechnology firms specializing in genetically engineered fruits and vegetables over which they have proprietary rights. Chemical and pharmaceutical companies may enter industrial farming in significant numbers in the future as the potential to genetically alter plants and animals to produce products with unique medicinal or industrial values expands (Zilberman and Sunding, 1995).

INDUSTRIALIZATION OF U.S. AGRICULTURE

The industrialization of U.S. agriculture involves the integration of formerly separate decision making sectors: input suppliers, farm operators, processors, grocers, and consumers. Integration is carried out through contractual arrangements or the vertical integration of separate units under single ownership. The use of production and marketing contracts was pervasive in some sectors of U.S. agriculture by 1970. For example, produced under contract were 92 percent of broilers, 85 percent of vegetables for processing, 70 percent of hatching eggs, 60 percent of turkeys, and 55 percent of citrus. Between 1970 and 1990 contractual arrangements also increased rapidly in the hog sector. In fact, the role of vertically integrated ownership increased substantially in a number of sectors during that time period. For example, between 1970 and 1990, integrated ownership increased (as a percent of production) from 30 to 40 percent of fresh vegetables, from 12 to 28 percent of turkeys, from 20 to 50 percent of market eggs, and from 12 to 33 percent of sheep and lamb production (O'Brien, 1994). According to Paarlberg (1995), the increase in contractual farming and vertical integration has been most spectacular since 1963 in eggs, cattle feeding, and hogs.

Paarlberg writes that the increase in contract farming and vertical integration has advanced most rapidly where certain circumstances have prevailed:

- where there was unexploited knowledge (that is, known in the laboratory but not applied on the farms) as in the poultry industry;
- where there were potential economies of scale, as in the production of hybrid seed corn;
- where standardization and steady flow to market of an improved product offered promise, as in pork production;
- where repetitive operations rationalized the use of supervised low-cost labor, as for processed fruits and vegetables;
- where new products not envisioned by the initial producer could be developed, as for potatoes;
- where there was opportunity for product differentiation, as in brand names for canned peaches; and
- where the family farm tradition was weak, as in the far west and the deep south.

In sharp contrast to industrialization, but again in response to highly differentiated consumer demands, is the rise in some areas of the nation of a segment of farmers engaged in production for niche markets. Niche marketers produce specialty crops and are typically independent, small-scale producers, located near large urban markets (such as in the northeast) and likely to market directly to small grocers, through roadside stands, or at urban farmers' markets. Although many of these direct or niche-market farmers require additional sources of income, they are able to take advantage of a rural life-style at the same time that they bring resources and vitality to the rural areas, and fill specialized food and farm-product demands.

Implications for the Future

Involving the Stakeholders

Emerging from this overview of the modern food and agricultural system are some important implications for the LGCAs' research, extension, and education programs. First, the overview highlights the high expectations the U.S. public has for the performance of its food and agricultural system and the diversity of the food and agricultural system's beneficiaries or stakeholders. The logical conclusion is that these stakeholders be involved in shaping the research and education agenda and that the projects and programs undertaken reflect their expectations. However, many beneficiaries of the food and agricultural system (such as urban and suburban residents) have had little knowledge of or connection to the college of agriculture, in spite of the fact that they, as consumers and taxpayers, clearly have a stake in the outcomes of the colleges' programs and activities. Unfortunately some groups (consumer and environmental groups, small and "alternative" farmers, minorities, low-income families) have felt or been perceived to be under-served or excluded (Beus and Dunlap, 1992; Castle, 1981; Debertin, 1993; Hassebrook and Hegyes, 1989; Madden, 1986; Marston, 1993; Strange, 1982), despite the fact that public funds provide the majority of the LGCA system's resources for research and extension and support academic programs as well.

A 1982 survey (which unfortunately has not been updated) showed that approximately 25 percent of U.S. households had ever contacted or used the extension service; approximately 10 percent had in the prior year (Warner and Christenson, 1984). Although the largest number of users lived in metropolitan counties, the largest percentage of users were nonmetropolitan (43 percent) as opposed to metropolitan (23 percent) residents, and more farmers (57 percent) were users than nonfarmers (25 percent). Users and nonusers also differed in demographics: younger and older adults were underrepresented in relation to middle-aged adults; blacks were underrepresented in relation to whites; and low-income families were underrepresented in relation to middle- and upper-middle income families (Warner and Christenson, 1984.)

Broadening and diversifying effective input into the priority-setting process is crucial to building the relevance of the Lucas' programs to a broader cross section of the population. It is a step that has a potential payoff for the colleges' traditional agricultural clientele because expanding input and participation by diverse groups is an important means of broadening the constituency base for food and agricultural science and education. Expanding access and participation also helps ensure that consumers and a broader set of potential users are familiar with production technologies developed at the colleges and can contribute effectively to assessments of the benefits and costs to society.

In fact, in recent years many colleges have begun to take the important step of soliciting broad stakeholder input and participation. For example, the W. K. Kellogg Foundation, through its Food Systems Professions Education Initiative, has funded 12 collaborative visioning processes (representing 26 universities in 21 states) designed to draw diverse constituencies together to focus on the role, mission, and structure of food systems education programs for the future (W. K. Kellogg Foundation). Resource adjustments are, however, difficult for all institutions, and many of the major issues of significant concern to the nation's communities and citizens have appeared to command minor portions of the Lucas' resources. These include (not ordered by priority) food safety, the linkages between diet and health, environmental quality, economic and equity issues such as opportunities for small-scale and family farms, rural vitality, and poverty and access to food (Reichelderfer, 1991; Robbers and Smith, 1995). For example, in the *Profile* report (Table 4-6:pp. 64-65), based on statistics from the USDA Current Research Information System (CRIS), which solicits and aggregates data about research conducted by experiment station and cooperating institution scientists, the data show that in 1992 "food and nutrition for optimal health" commanded a little more than 3 percent of total scientist years and "social sciences issues" accounted for approximately 12 percent of all scientist years (National Research Council, 1995a). In 1994—using a slightly different aggregation

USDA'S CURRENT RESEARCH INFORMATION SYSTEM FOR FOOD AND AGRICULTURAL RESEARCH

Food and agricultural research benefits from an inventory system called the Current Research Information System (CRIS). CRIS is the USDA documentation and reporting system for publicly supported agricultural, food and nutrition, and forestry research in the United States. It was initiated in 1966 and designed to assist persons who carry out joint research program planning, evaluation, and coordination. Research conducted by USDA, state agricultural experiment stations, forestry schools, 1890 colleges, colleges of veterinary medicine, and other institutions is included.

CRIS codifies research in several different ways. One way is by the commodity or resource that is the focus of the research—for example, soil and land, wheat, or farmer cooperatives. A second classification is research goal. Nine general goals are available, such as to "protect forests, crops and livestock from insects, diseases, and pests," "produce an adequate supply of farm and forest products at decreasing real production costs," and "protect consumer health and improve nutrition and well-being of the American people." Each general goal encompasses as many as a dozen subgoals. A third classification is research program group. There are eight groups, including natural resources; forest resources; crops; animals; people, communities and institutions; competition, trade, adjustment, price and income policy; general resource or technology; and food science and human nutrition. Researchers are also asked to report their funding sources, the area of science, the percentages of the research that are basic, applied, and developmental, and the staff effort devoted to the project.

Despite the comprehensiveness of the CRIS system, some users have found it difficult to determine how many resources are devoted to specific goals, such as reducing pesticide use or exposure. Because of the general nature of the categories, it is difficult to detect shifts in research emphasis. Also, researchers do not report anticipated impacts or specific beneficiaries. CRIS should be maintained because it is a consistent, historical record of experiment station research. Improvements should enhance the inventory's usefulness for assessing new directions for publicly funded research investments and research contributions to public policy goals.

SOURCE: US. Department of Agriculture. 1995. Cooperative State Research, Education, and Extension Service, Inventory of Agricultural Research Fiscal Year 1994, August 1995.

of research projects—experiment stations and other cooperating institutions committed 4.7 percent of their research expenditures to "food science and human nutrition" and 3.8 percent to research on "people, communities, and institutions" (US. Department of Agriculture, 1995). The principal focuses of agricultural research continue to be crops, animals, and forest resources, although the current research reporting system, because of its design, makes it difficult to accurately assess the contributions of these research categories to specific public issues and particular constituencies.

Several national and regional planning bodies and the US. Congress play important roles in identifying priorities for food and agricultural system research and education (Table 2-1). For example, the Joint Council on Food and Agricultural Sciences (Joint

TABLE 2-1 Planning or Advisory Body Priorities for Food and Agricultural System Research and Education, 1994

Joint Council on Food and Agricultural Sciences	National Agricultural Research and Extension Users Advisory Board	Experiment Station Committee on on Organization and Policy
Achieve economically viable production systems compatible with environmental and social concerns.	Profitability and competitiveness: e.g., develop profitable production systems that reduce agriculture's contribution to water quality problems.	Environment and natural resources
Provide a safe, affordable, reliable, and nutritious food supply.		Nutrition, food safety, and health
Educate agricultural scientists and professionals to meet future challenges.	Consumer and post production issues: e.g., determine the role of diet in obesity, eating disorders and chronic disease.	Processes and products: e.g., new and improved nonfood products
		Economic and social issues
Improving global competitiveness of the U.S. food, agricultural, and forest products.	Sustainable agriculture.	Animal systems
Empower individuals, families, and communities to improve their quality of life.	Economic development: e.g., encourage development of opportunities for niche-market farmers engaged in activities such as organic and alternative production enterprises.	Plant systems

Council) was established by Congress to improve the planning and coordination of research, education, and economics programs (1977, 1981, 1985, and 1990 farm bills). Its membership includes producers, the food and agribusiness industries, state and federal agencies, and land grant and state universities. The Joint Council recommends priorities and identifies expected outcomes each fiscal year.

The National Agricultural Research and Extension Users Advisory Board (UAB), also authorized by the 1977, 1981, 1985, and 1990 farm bills, represents consumers, environmentalists, nutritionists, and laborers as well as farmers, ranchers, farm suppliers, and food processors in recommending initiatives and shifts in direction for food and agricultural research and education (National Agricultural Research and Extension Users Advisory Board, 1995; see Table 2-1). The U.S. Congress, through the research title of the farm bills, establishes broad goals for the national research system based on input from the executive branch and other planning and advisory groups. In response to input from specific constituent groups, Congress also authorizes and appropriates funds for special research programs. For example, the 1990 farm bill placed particular emphasis on alternative agricultural research (Smith, 1995). The challenge continues to be translating these priority-setting processes into resource allocation decisions at the colleges and experiment stations.

Guidance in determining research priorities is provided to experiment stations by the National Association of State Universities and Land Grant Colleges' (NASULGC) Experiment Station Committee on Organization and Policy (ESCOP), which annually conducts an agricultural budget review and priority-setting exercise. [A similar exercise is conducted for extension priorities by NASULGC's Extension Committee on Organization

and Policy (ECOP). ESCOP's priorities are, however, broad and sufficiently all-encompassing that it is easy to include any research project within one of its priority designations (see Table 2-1 and the Profile report, p. 63). Its recommendations apply to the entire experiment station research portfolio and thus are not useful for differentiating priorities for research conducted with federal, state, or private resources. At the state level, a variety of methods to influence the direction of research conducted with state or federal formula funds are used. Methods range from close control by the experiment station director to virtual freedom for college departments or individual researchers to use internally allocated funds to pursue the research issues they deem most important. The degree to which users and stakeholder customers of the experiment station research program are involved in priority setting also varies widely among states, despite the efforts mentioned above.

The focus of experiment station research supported by federal competitive grants is determined by the nature of the research solicited by the grant programs' Requests for Proposals (RFPs). The RFPs for the USDA's National Initiative for Research on Agriculture, Food, and the Environment (NRI), at present the largest source of competitive grants for agricultural research, are written by NRI program directors.[1] The program directors have operated without a strategic departmental policy for research agenda setting and prioritization (Office of Technology Assessment, 1995). Although these program directors solicit the opinions of representatives of various research user groups, nonscientist stakeholders are not directly involved in decision making, and there is no way to gauge the extent to which informal advice from stakeholders affects program directors' decisions. There is a need to go further in narrowing the gap between stakeholder input and the outcomes of resource allocation decisions.

RECOMMENDATION 1. *Receipt by LGCAs of USDA-administered research and extension funds—including formula funds and competitive grants—should be contingent on their ability to demonstrate that a wide variety of stakeholders have effective input into a systematic prioritization (no less often than biennially) of research, extension, and joint research-extension issues, that specifies areas of increased and decreased emphasis. Further, LGCAs must demonstrate that a wide variety of stakeholders are consulted in resource allocation decision making processes. (Also see Recommendation 9.)*

Working with producers

The second implication of an expanded perspective on the food and agricultural system is the challenge and complexity of serving and meeting the needs of today's and tomorrow's agricultural producers. As indicated, producers are an exceedingly diverse group, spanning vertically integrated firms and their contractors, large corporate farms

[1] Two reports from the National Research Council's Board on Agriculture focused on USDA's National Initiative for Research on Agriculture, Food, and the Environment (NRI). The *first, Investing in Research: A Proposal to Strengthen the Agricultural, Food, and Environmental System* (National Research Council, 1989b), proposed a substantial expansion of the use of competitive research grants in agriculture and resulted in the creation of the NRI by the 1990 farm bill. The board's proposal suggested the six program areas that still form the core of the NRI program. The original proposal also supported four types of competitive grants: (1) principal investigator, (2) fundamental multidisciplinary team, (3) mission-linked multidisciplinary team, and (4) research strengthening. Major emphasis was to be given to multidisciplinary teams. The second Board on Agriculture report, *Investing in the National Research Initiative: An Update of the Competitive Grants Program in the U.S. Department of Agriculture* (National Research Council, 1994a), evaluated the status of the NRI. The second report did not identify any significant drift from the program's (and the board's) original objectives, although some original objectives—such as 50 percent multidisciplinary research—have not been fully realized. (See committee's discussion of its support for multidisciplinary research in Chapter 4.)

(that are often family-owned), moderate-sized family farms, niche marketers and other "alternative" growers (such as organic farmers), and low-income, limited resource farms. On average, farm family incomes are on a par with average income for nonfarm families; and like nonfarm families, U.S. farm families span the income scale from very wealthy to exceedingly poor (Dacquel and Dahmann, 1993). As was reported in the *Profile* report, some farm families have few, if any, economic alternatives; others already earn most of their income off the farm (National Research Council, 1995a). The diversity of producer groups within the production sector provides a tremendous range of experiences and, thus, also generates a wide array of specialized research and information needs, thereby posing significant challenges to the research, academic, and extension programs in the LGCA system.

It is important for the LGCA system to retain and enhance its relevance to the agricultural production sector broadly defined. The science base for the next generation of technological advances and the training for the next generation of the agricultural work force must be relevant to the commercial sector because the performance of commercial agriculture is integrally linked to

- U.S. economic performance,
- the stock and quality of the natural resource base,
- the sector and nation's international competitiveness, and
- the world's ability to produce sufficient food at reasonable cost for a still rapidly expanding population.

At the same time, the LGCA system must be relevant to the multitude of smaller producers who bring a diversity of skills, ideas, and practices to agriculture, bring economic activity to rural communities, enhance the natural landscape, and supply a variety of specialized market niches. Many believe that without this segment of production agriculture, the nation would be less vital and rich in life-style and economic alternatives. Service to the country's low-income or limited-resource farmers is no less (and may be even more) a land grant mandate. The land grant system originated to serve the working class through assuring its access to science-based knowledge and educational opportunities; in certain regions and pockets of the country, that mandate is no less critical today than in the system's earliest years.

RECOMMENDATION 2. *In light of the changing structure of agriculture and the importance of diverse participants in production agriculture, the LGCA system should critically assess the needs of all producer population groups, develop priorities and targeted programs for each, and adjust technology transfer and information delivery modes appropriately.*

This does not mean that the system must be all things to all people. On the contrary, LGCAs should focus on the highest priority research and information needs not likely to be met by the private sector. Increasing rates of agricultural research and information privatization, as discussed by Wolf (1996), may, in effect, free some LGCA resources that can then be devoted to a broader based clientele. But because different types and differently organized producer groups receive different types and degrees of assistance, attention, and input from the private sector, the committee recommends that the LGCA system assess and address the diversity of needs that remain in the public purview. Low-resource producers are likely to require quite different and relatively more public assistance than are highly specialized or vertically integrated producers.

Understanding the Growing Role of Privatization and Developing the Knowledge Base

The third implication is the need for a comprehensive understanding of how the new science is influencing incentives for research by private actors in the food and agricultural

system and the implications of those new incentives for the LGCA system's own role. Advances in science are contributing to the restructuring of the food and agricultural industry, redefining educational needs and technological opportunities, and realigning relative roles for public and private research. The increasing importance of biotechnology, coupled with patent protection for genetically engineered organisms, has significantly enhanced opportunities to engage in proprietary biological research (Office of Technology Assessment, 1992). This has increased agricultural and food systems research by private firms, such as biotechnology companies as well as by seed, food manufacturing, and pharmaceutical companies (Fuglie et al., 1996). Private sector agricultural research expenditures are estimated to have exceeded $3.4 billion in 1992, up from only $0.2 billion in 1960 (an annual average growth rate of 3.5 percent in real terms). Investments have grown most rapidly in relation to agricultural chemicals, animal health, plant breeding, and applications of biotechnology (Klotz et al., 1995). Private funding is also increasing for agricultural research on the large commercial and vertically integrated farms. Firms develop crop varieties, livestock, and fish stock with carefully selected traits; growth hormones and pharmaceuticals; and biological controls. They contract with growers for field testing and crop, livestock, and fish production; and retain proprietary rights to the genetically engineered product or stock. Because of the strong proprietary incentives, they also conduct adaptive research to determine optimal growing or production conditions, feeding rations, and management practices.

The advent of biotechnology greatly expands opportunities in food and agricultural research (Doyle, 1985; National Research Council, 1987); it also blurs distinctions that have been useful in the past for defining public versus private roles. The LGCA system needs to pursue opportunities in biotechnology to the benefit of the food and agricultural system, with a special responsibility for assuring that the benefits of new knowledge and technological advances are distributed broadly. Equally important is the opportunity, as private research in animal and plant breeding (and accompanying adaptive research) expands, to refocus public research and extension funds on the many critical research and extension needs where there are limited incentives for private funding.

The committee believes the public food and agricultural research and extension system—encompassing both intra- and extramural programs—would benefit from further study of the implications of new developments in biotechnology for the division of labor between public and private research entities and recommends that such a study be undertaken.

A NEW GEOGRAPHY AND NEW PARTNERSHIPS

The LGCA system has until recently been comprised of 76 institutions in 50 states, 6 territories, and the District of Columbia (National Research Council, 1995a). In 1994 the 29 Native American colleges that comprise the American Indian Higher Education Consortium were granted land grant status. The focus of this report, however, is the 1862 and 1890 colleges because at the time the committee's charge was developed, the land grant system was composed only of the 1862s and the 1890s. All LGCAs have some important commonalities derived from the land grant purposes, philosophies, and formula funding base, although they represent considerable diversity in institution type, including size, populations served, funding portfolio, and university context (such as whether the university is a nationally prominent research institution).

For the LGCA system to adopt a research and education agenda that reflects an expanded and inclusive view of the food and agricultural system (encompassing the priorities of consumers and the many specialized needs of diverse producer groups), it must realize organizational efficiencies and strengthen partnerships that have the potential to enhance the scope, quality, and relevance of the knowledge base. Although new incentives for private sector research and extension help to enlarge the entire pool of resources for scientific discovery and technological development, the LGCA system is essentially being asked to address a wider array of issues with current or few new

resources. The system, however, has the potential to draw on its resources more efficiently through regional initiatives and centers; through multi-institutional, collaborative efforts in teaching, research, and extension; and through the use of advanced information and communications technologies. The committee refers to these types of arrangements as a "new geography." The internal incentives to undertake multistate and multi-institutional collaborative activities have been lacking in the past. They may, however, be increasing with growing constraints on individual state and university resources; and, as recommended below, the federal government can enhance the system's incentives to collaborate through the design of its grant programs.

In the system's early years there was strong justification for a land grant college located in every state—farming was the country's principal occupation and industry, the nation was sparsely populated, transportation networks were poorly developed, rural people were isolated, and there was very little access to higher education for the working classes. The federal land grants (and later cash grants) were an important motivation to states to initiate and support colleges, particularly ones that would focus on studies useful to the advancement of peoples' economic status and the country's industrial base (Cochrane, 1979). Although a college in every state was the logical ideal at the time of the system's inception, the committee does not believe there is any ideal number of colleges of agriculture either today or in the future. Given modern transportation and telecommunication networks, and the nature of modern food and agricultural system issues and science opportunities, there are many opportunities and reasons for more efficiently and effectively utilizing the system's resources. This new geography can capitalize on the diversity that already exists within the land grant system.

The original land grant colleges share legislative roots in the Morrill Acts of 1862 and 1890, Hatch Act, and Smith-Lever Act. National-and regional-level research, extension, and academic planning committees link the institutions' agendas in a very general way, as described above. Scientists collaborate across institutions; there are examples of regional research efforts; "articulation" and "bridging" agreements (written agreements that facilitate the transfer of students among institutions and the exchange of academic credits) exist; and the use of the Internet as an educational platform is occurring, as examples in this report indicate. Many of these efforts are, however, informal or have the potential to be much more effective.

The Case for a New Geography Has Several Foundations and Dimensions

First, states are often not the best unit of organization or operation for food and agricultural system issues. There are many issues and problems that call for regional or multi-institutional efforts. Many natural resource and environmental issues, such as watershed management, cross state lines. Many consumer issues, such as nutrition and disease, know no political boundaries, or they may be specific to similar populations located in spatially separate areas of the country—such as the relationship between diet and non-insulin dependent diabetes in the Hispanic population (American Diabetes Association, 1993). Even within the farm sector, production issues are often pertinent to producers in a region that comprises all or parts of several states or regions in several noncontiguous states. In fact, statistical analysis reported in the *Profile* report (National Research Council, 1995a:pp. 93–96) suggests that significant regionalization of research focus has already occurred within the LGCA system. The analysis shows that LGCAs can be grouped into regional clusters defined by the focus of their commodity-specific research. For example, five contiguous states have research programs that emphasize corn, soybeans, and hogs; eight contiguous states have research programs focused on cattle, wheat, and vegetables; two contiguous states emphasize rice, soybeans, and beef cattle (Figure 7-4, p. 95, in the *Profile* report).

Second, a broadened research and education agenda requires more efficiency. Every college cannot do everything; regional and multi-institutional collaborations would enable individual institutions to become more specialized, and to develop more depth in

their specializations, because their students and clientele would be better able to access the courses and knowledge bases of other colleges in other states. Increased specialization and collaboration would also reduce unnecessary replication of programs within the national system. In the *Profile* report, data collected from the LGCAs indicate that for undergraduate degrees in 1992 the LGCAs together offered (as selected examples) 13 programs in poultry science, 92 programs in general and specific fields of animal sciences, 35 programs in agronomy, and 129 programs in general and specific fields of plant science, and 45 degree programs in agricultural economics (a program was included in the FAEIS data base if it granted at least one degree that year). At the doctorate level there were 50 programs in various animal science fields and 111 in plant science fields (Table 3-9, pp. 49–51, in the *Profile* report). In that same year LGCAs granted 230 doctorate degrees in animal sciences and 436 in plant sciences (Tables 3-7 and 3-8, p. 46, in the *Profile* report), an average of about 4 per program. The data also show that a relatively small percentage of the land grant colleges enroll a much larger percentage of the land grant students, suggesting that some programs may have too few students to support them effectively (Tables 3-3 and 3-4, p. 43, in the *Profile* report).[2]

Third, the future of smaller, less well-supported institutions may depend on a new geography and accompanying partnerships. The 1890 institutions and indeed many of the smaller 1862 colleges of agriculture play important roles in providing access to higher education for minority group students, young people raised in more remote rural areas, and residents of U.S. territories, although they may have small absolute numbers of students. The future of some such colleges, in an era of significant budget constraints, may hinge on their being integral components of a national system of colleges. In other words, they must be able to expand resources for both faculty and students through research and educational partnerships and links into other universities' programs, while strengthening their own unique specializations in higher education, outreach, and research.

Fourth, a new geography—an interconnectedness with other institutions and other parts of the country—offers both students and faculty the opportunity for broader exposure and, at the same time, expands access. Colleges of agriculture have been criticized for being too insular and too parochial in focus (Busch and Lacy, 1983; Hadwiger, 1982; Mayer and Mayer, 1974). Bridging and articulation agreements, faculty and student exchanges, collaborative research and educational programs, and distance learning opportunities expose students and faculty to new and different ideas, perspectives, values, and cultures, as well as new material. In a highly interdependent world and global economy for food and agricultural products, the ability of college graduates to operate in a climate of great diversity is an important and valued skill (Wall Street Journal, 1995). In a food and agricultural system that includes stakeholders with many different and, at times, conflicting interests and goals, a work force with broad exposure and an open mind is essential.

New arrangements are also needed that can bring about a stronger interface between the colleges and urban and suburban areas. As discussed above, agriculture is no longer an exclusively rural enterprise and yet the LGCA system's strongest connections continue to be, understandably, with rural communities (Warner and Christenson, 1984); this was expressly noted during the land grant committee's public forums held in the spring of 1995. A food and agricultural systems approach requires a better connectedness to consumers and consequently to the urban and suburban centers where most of them live.

[2] While there is no widely accepted "rule of thumb" for the number of students a degree program must have in order to be viable or successful, there is some evidence that larger programs tend to receive higher quality ratings by experts. For example, Research-Doctorate Programs in the United States: Continuity and Change (National Research Council, 1995c), which ranked doctorate programs in 41 fields at 274 U.S. universities, reported that top-rated programs in most fields tend to have a larger number of faculty and more graduate students than lower-rated programs.

Among the possibilities is the relocation of some of the experiment stations' many branches—most of which are now located on rural sites and engaged in plant and animal research of direct interest to that location—to urban and suburban settings.

RECOMMENDATION 3. *Federal programs and policies should enhance the LGCA system's efforts to realize organizational efficiencies and synergies that broaden and deepen the system's expertise and expand access and relevancy. Significant shares (25 percent or more) of total current USDA-administered extramural funds—including formula funds and competitive grants—for food and agricultural research, teaching, and extension should provide incentives for*

- regional centers, consortia, programs and projects that effectively integrate and mobilize multistate and multi-institutional (including 1862, 1890, and 1994 colleges') resources; and
- distance learning and other technologies that expand access, broaden clientele, and enhance multi-institution collaboration in teaching, research, and extension.

Regional Research

Many important research problems are common to many of the experiment stations, for example, weed control in corn or mastitis in dairy cattle. To facilitate cooperative research, 25 percent of formula funds are now expended for regional research. This is accomplished via the funding of hundreds of USDA Regional Research Projects ranging from dairy cattle genetics to economic risk assessment. Each project requires a formal proposal that defines the work to be done, the participants, and the respective experiment station resources to be devoted to the project. Projects are reviewed by a committee of nine experiment station and home economics research directors, which recommends projects for approval by the administrator of USDA's CSREES (Lipman-Blumen, 1989). Each project is approved for a 5-year period, after which a formal revision is required that must be re-reviewed. This system has succeeded in the past by avoiding duplication, stimulating meaningful replication of experiments, and benefiting from the synergistic ideas of the typically 5 to 25 participating scientists.

This seemingly excellent mechanism of organizing agricultural research, however, has some major limitations. For example, it is inflexible with respect to which institutions receive the funding because funds are allocated by formula rather than by merit. Also, in nearly all cases, the participating scientists are all in the same field, for example, plant pathology. Furthermore, the process is too often ad hoc in that projects are initiated (or continued) by scientists without thoughtful direction or input from other stakeholders or priority setting by the system. In practice, annual regional meetings are primarily mechanisms for information exchange, a function that seems less necessary given modern means of electronic communication and networking. A recent review of the agricultural research system concluded that, "On the whole, it would seem that too little progress has been made in the direction of developing institutions that will deal efficiently with problems for which the jurisdiction is neither a state nor the nation as a whole" (Alston and Pardey, 1995).

An alternative approach to regional efforts is that used by the Sustainable Agriculture Research and Education (SARE) Program, a small USDA-CSREES competitive grants program with regional orientation. Regional administrative councils manage the SARE programs, which are composed of farmers using sustainable agriculture systems and practices, agribusiness, nonprofit organizations with demonstrated expertise, state departments engaged in sustainable agriculture programs, as well as leaders from the federal and state agricultural research and extension systems. The regional councils are responsible for project review, selection, and recommendations for funding of grants to be awarded. A national advisory council is comparably composed and makes recommendations for project approval to the Secretary of Agriculture. Users of research are centrally involved in guiding the research program and full partners in it. This approach is worthy of examination as an appropriate alternative means of federal-state-industry pooling of resources for regional efforts in research, teaching, and extension.

Coordination Could Create Synergism in Teaching

Colleges of agriculture are attempting to broaden their curricula to reflect a more comprehensive and global vision of the food and agricultural system. This effort is extremely important to the colleges' futures, although it understandably generates tensions. Teaching programs must remain relevant to production issues facing the states' producers. The fact is, however, relatively few students—even in states with large farm sectors—will own or operate farms and ranches. The colleges must also prepare students to go on to graduate programs in business and economics, science, veterinary and other medical fields, and law; or to work in a broad range of public and private sector jobs and industries in and outside the state.

To meet this challenge, many colleges are expanding their curricula—as reflected in an array of new college names, courses, centers, and institutes—but many are also finding challenge in defining a new and coherent focus. Many if not most food and agricultural specializations, such as nutrition and food safety, biotechnology, agribusiness and management, animal sciences, and information technologies are broadly applicable nationally and internationally. However, some modern issues and problems—particularly in the primary production sector—are keyed to certain states or regions, or are more important in some than in others.

Some degree of specialization has, of course, emerged. Some colleges, by reason of their geographic location, emphasize fisheries or forestry or water resources or arid land management or food distribution systems. However, as discussed above, there may still be more-than-needed repetition of traditional departments and degree programs within the nationwide system. The committee believes it is possible to enhance the efficiency of the instructional delivery system by reducing unnecessary replication and allowing colleges to develop more depth in specialized educational niches.

Colleges can expand the courses available to their students, while emphasizing their own "in-house" specialization and expertise, through articulation agreements with other geographically accessible schools and the liberal use of telecommunications. For example, Cornell University, Rutgers University, the University of Vermont, and the University of Maryland are working together to design an experiential summer education program in organic production that builds on the expertise of each institution. Students at any of the four institutions will be able to match their interests by participating in a summer program at the appropriate school (Powers, 1995). The LGCA system has begun (and should continue) to capitalize on innovations in telecommunications and computer networks to develop distance education and virtual courses that draw on the specializations of other institutions or that integrate the specializations of several institutions.

A Market-Based Agricultural Extension System

The improvements in transportation and communication networks mean there are opportunities to reconsider delivery points for extension services using advanced delivery technologies such as telecommunications and computer networks. In other words, the geography of extension can be very different than it once was. Producer clientele can today communicate and work more directly with the university-based specialists and research scientists. Contemporary and future extension services can cross political boundaries and be more attuned to the market in which a product or service of the land grant university can be applied.

In the future, one land grant institution may be the administrative base for a regional or market-based extension effort with all, some, or many universities in that market area providing research support. For example, the New England Cooperative Extension Consortium has made significant strides toward coordinated cooperation. The impetus for the New England consortium came from the presidents of the New England land grant universities, who asked their cooperative extension directors to consider a regional plan to confront increasingly scarce resources, new demands, and the need to maintain and enhance access and quality in the face of resource constraints (Sanderson, 1992). They continue to struggle with obstacles, such as allocating travel costs when specialists

DISTANCE EDUCATION

Distance education is rapidly becoming a reality. In the land grant system, A* DEC is a consortium of 46 universities that uses distance education technology to share undergraduate- and graduate-level courses, extension programming, research findings, and international speakers. Current technologies include audio/video via satellite, phone, fax, and computer systems. Programs include for-credit courses, short courses, workshops, certificate programs, and conferences. More than 30 courses were offered in the 1995-1996 academic year, including courses in marketing, meteorology, biochemistry, nutrition, community, statistics, and wildlife conservation.

At Iowa State University, the Internet as a course platform has been experimented with by Professors Takle and Taber, who offer a class on the global environment (cross-listed in Meteorology, Agronomy, and Environmental Studies) through the Internet. They say, "the computer allows development of a more complete information base for the course that may consist of text, colored photographs, animated images, video, and audio, … and the merging of real-time information such as weather forecasts, satellite observations of sea surface temperature, and ozone hole measurements." The computer also enables students to react to information in the data base and to extend course interaction beyond class time. Accessibility is enhanced, the professors argue, because students who have access to work stations can gain access to the homepage and information base 24 hours a day, 7 days a week. They also feel that the Internet-based course promotes continuing education because students can continue to participate in the course after it is over and even after they have graduated.

cross state lines, true regionalization of staffing decisions, and philosophical differences regarding the role of the consortium director (R. L. Christenson, University of Massachusetts, personal communication, 1996); nonetheless, the guiding principle for new and existing consortium extension programs is that they capitalize on the breadth and depth of extension's resources in two or more states. To demonstrate that principle, the six New England state extension systems established an agreement for sharing the expertise and resources of poultry specialists. They developed a regional approach to train faculty and staff to carry out extension's Expanded Food and Nutrition Education Program (EFNEP). The states also combined their resources for training in public policy education (Sanderson, 1992). The work of the consortium has led to increased multistate efforts in youth, family, and water quality programs (R. L. Christenson, University of Massachusetts, personal communication, 1996).

Multifaceted Issues Require New Partnerships

As many colleges have recognized, there are important reasons to build partnerships among departments and among disciplines within the college, and among colleges within the university. Understanding and resolving many food and agricultural system issues requires an approach that accounts for complex interactions among physical, biological, social, and economic processes (Lacy, 1993; Lockeretz and Anderson, 1993; National Research Council, 1993). LGCAs must also build stronger bridges to other university colleges and departments if the best science is to be used to solve agricultural

A SHORT COURSE BY SATELLITE

South Dakota State University created a cattlemen's satellite short course as a distance learning program for people involved in the cow-calf phase of beef production. This program was conceived by the Cooperative Extension Service and consisted of 15 90-minute seminars broadcast via satellite on a biweekly basis to sites in 46 states and 2 Canadian provinces. Approximately two-thirds of each broadcast was devoted to lecture and one-third was devoted to questions that were either phoned or faxed in from viewers. A facilitator at each regional site coordinated the local meetings and assisted group discussions and interactions. Seminars were augmented with handouts and correspondence mailed to participants between seminars. The format allowed for many of the topics to be presented during the same time frame that viewers were making decisions on the farm or ranch regarding those issues. Viewer surveys reflected that 60 percent of the participants were cattle producers, 24 percent were involved in some form of agribusiness (banking, veterinary medicine, sales, marketing), and 16 percent were extension personnel.

and food system problems. Collaborative efforts in both teaching and research, and designing courses that fill both college and science or college and humanities requirements are ways to strengthen these linkages (see Chapter 3, Teaching). Greater integration of agricultural and resource economics programs with general economics programs, of biotechnology programs in colleges of agriculture with those in medical schools and other units, and of the plant sciences with botany, are examples of situations in which greater integration promises to have a high payoff.

The USDA's NRI program has been an important (in fact, the only formal) means of drawing scientists from outside the colleges' experiment stations into agricultural research, broadening the science base, and expanding the opportunities for collaborative research between experiment station and other scientists (National Research Council, 1994a). The extension component of the LGCA system also has an important role in building bridges between the college of agriculture and the rest of the university. Over the years, extension's programs have extended into nonfarm areas, reaching out to low-income consumers to provide nutrition education and to rural and nonrural communities to provide services in economic, community, and human development (see Chapter 4, Extension). The knowledge base for these programs may lie outside the college of agriculture, offering the opportunity to draw other components of the university into outreach and public service efforts coordinated or led by the college of agriculture, or by central extension offices with strong participation by colleges of agriculture.

The partnership between the colleges of agriculture and the federal government also calls for attention and enhancement. The importance of the federal partner as a funding source was highlighted during the economic recessions that struck many states in recent years. During the 1987–1992 period, for example, federal funding of LGCA, forestry schools, and veterinary medicine college research (including support from competitive and special research grants as well as formula funds) grew 10 percent per year, while state funding to the system increased 5 percent per year (nominal dollars) (Table 6-1, p. 76, in the *Profile* report). As constraints on all public funds for research continue to tighten, the LGCAs need (and should encourage and welcome) strong national leadership in building support among all U.S. residents and federal policy makers for food and agricultural science and education.

INTRAMURAL STRUCTURAL ISSUES

The LGCAs in most university systems are often semiautonomous relative to most other academic units in the system, in part because of funding structures on the federal, state, and local levels. Many areas of study and subdisciplines applied to the food and agricultural system have developed in the colleges separately from the development of parallel, more broadly based disciplines in other units: for example, agricultural economics versus economics in business or arts and sciences colleges; agricultural business versus colleges of business; agricultural communications versus schools of communications; agricultural education versus colleges of education; rural sociology versus departments of sociology; and biological sciences versus similar departments in colleges of arts and sciences.

Agricultural engineering in many land grant universities is housed in some joint arrangement between the college of agriculture and the college of engineering, which may be a forerunner of other closer articulations. The committee believes such articulations are important to the future of the land grant system as the "peoples' universities." This is because the well-developed practical orientation and responsiveness to clientele that characterize the colleges of agriculture can positively influence the culture of other land grant university departments and colleges in directions consistent with contemporary demands on higher education. The committee also believes such articulations are vital to enhancing the quality of teaching, research, and extension programs of the colleges of agriculture.

RENEWING THE TRIPARTITE MISSION: INTEGRATING TEACHING, RESEARCH, AND EXTENSION

The federal vision for the land grant colleges began with the 1862 Morrill Act, which gave the colleges their teaching responsibilities. The vision expanded with the Hatch and Smith-Lever Acts to encompass the functions of research and extension in addition to teaching. Over the decades the land grant college has become identified with an educational system that integrates teaching, research, and extension. Other colleges and schools of the university provide instruction, conduct research, and engage in outreach or extension activities; but the LGCA system's major contribution and mark of pride has been its balanced commitment to the "tripartite mission."

The LGCA system's commitment to the integration of teaching, research, and extension is extremely valuable because of the linkages it can engender among science, learning, and public service and must therefore be renewed and strengthened. Unfortunately, the separate administrative structures that have grown up around academic programs, research, and extension, which stem from the separate pieces of land grant legislation may hinder integration of the three functions and their programs (Beattie, 1991). Split appointments, separate structures and budgets, and separate federal grants programs for research and extension may in fact be divisive rather than integrating forces, and the committee strongly encourages LGCAs to rethink these often divisive arrangements. Some colleges of medicine simultaneously run hospital and health service units within states, offer graduate and undergraduate courses, conduct research, and provide public service information; yet their faculty do not divide their time between, for example, an experiment station for research and an extension service for off-campus activity (Meyer, 1968). When LGCA deans were asked by Meyer (1995) if they thought teaching, research, and extension functions were integrated effectively in their institutions, they indicated that there were problems and that the most improvement was needed in the interface between research and extension (Meyer, 1995).

Linking Teaching to Research and Extension

The effective integration of teaching, research, and extension involves students in both the process of discovery and the delivery of research results and new knowledge to the public. Thus an integrated three-part mission links the academic experience directly to both the conduct of science and public service.

There are many good examples of research being brought to the classroom and of students working with off-campus stakeholders through internships with cooperative extension. However, there are also indications that the three functions are not well knit into the fabric of the student's educational experience at an LGCA. One indicator is faculty appointment types. As was noted in the *Profile* report, most LGCA faculty appointments combine research and teaching or research and extension but rarely combine teaching and extension or all three responsibilities (National Research Council, 1995a). There are practical reasons for this—divided administrations, divided funding, etc. Thus the direct role of extension or the extension faculty in on-campus instruction does not seem to be well developed or integrally related.

Another indicator of the lack of integration is the diverging interests of undergraduate students, faculty researchers, and extension staff. On average, the fields in which the majority of undergraduates major (such as agribusiness and agricultural economics and natural resources), the majority of research scientists specialize (such as plant and animal sciences), and many extension staff are involved (such as nutrition education and youth, family, and community leadership development) are not the same (National Research Council, 1995a). It is understandable, and not necessarily inappropriate, that the focuses of the three functions diverge as each adapts to different external and internal demands and incentives. However, this divergence limits the ready-made opportunities to combine research and extension with academic programs.

Another barrier to an educational experience based on the integration of teaching, research, and extension is extension's status at many universities. In many states extension does not seem to be an important voice at the university; in some states it has become effectively separate from the colleges' academic and research missions; in some states extension specialists do not have faculty appointments. A more integrated role for extension in campus education and university affairs has the potential to enhance the public service component of the LGCA education and to complete the educational continuum spanning discovery to application.

The link between student education and research occurs mostly through the participation of students on research teams, although many faculty also bring their research to the classroom. Students, as part of a research team, have important responsibilities and develop scientific abilities relatively rapidly in this environment. They learn by doing, and this on average leads to superbly trained personnel capable of solving problems. This system evolved at land grant universities and is widely emulated at other research universities. Graduate students have the most substantive involvement in this relationship; however, increasing numbers of undergraduates are also engaged in research as part-time employees and interns (see Box text, p. 37).

There are, however, imperfections in the student-research link. For example, graduate students often do large amounts of menial labor, research projects are slowed by having continually to train new personnel, and faculty and students must balance their research and teaching or course work responsibilities. Nevertheless, the benefits greatly outweigh these imperfections. A more serious problem is communicating the value of this system to the public, particularly to those who fund land grant universities. The value of research for graduate training—and, conversely, the value of graduate training for research—is very much underappreciated. In truth, teaching and research usually are so intertwined that to separate them budgetarily is illogical. Nevertheless, partly because there are two products—new knowledge and trained personnel—and partly because there are different funding sources and accountability channels, this is precisely what is done.

A growing concern is that although superb scientists are produced, it is a system that emphasizes the production of scientists with specialized disciplinary expertise at the

expense of developing other skills. Increasingly, industry, government, and even academia seek graduates at all degree levels—including Ph.D.—who are broadly trained, have multidisciplinary expertise, are flexible, are oriented toward teamwork, and have excellent communication skills (National Research Council, 1995b). The limitations of research assistantships as the only means of preparing students for science and engineering careers is discussed by Good and Lane (1994), who argue that assistantships too often bind students to their faculty mentors for financial support and thus limit innovative learning experiences such as participating in collaborative research with private corporations (Good and Lane, 1994). The LGCA system, given its history of practical education and close ties to farm and agribusiness clientele, is well suited to provide an educational experience that develops modern work place skills and experiential breadth as well as excellent research and problem-solving skills and disciplinary depth.

An important and growing link between teaching and extension occurs through the growing need for lifelong educational opportunities. The need for lifelong learning has grown with the increase in life expectancy, the significant speed with which new knowledge is generated in society, and the rapid reconfiguration of the national and international economy. The scientific and technological cadre that serves the food and agricultural sector needs to be kept abreast of the new knowledge being developed and its application to problems in society. In addition, many people who missed educational opportunities early in their lives find career advancement limited without additional formal education. Although the committee was unable to devote time and attention to this issue, it does believe that formal programs of midcareer education are needed and that the needed level of these programs is likely to be more than can be provided through current extension services. This is an area that calls for attention and combined commitment from both extension and academic program administrators.

Research-Extension Linkages

One aspect that has made the land grant system unique is the way it has linked agricultural research and off-campus extension education. Historically, university specialists and county extension agents have worked closely with farmers and other users of experiment station research, translating research findings for them and advising them about how to use research information. Sometimes the agents have interpreted and communicated back to researchers and teachers in experiment stations and university departments the problems and research needs of farmers, rural communities, and other client groups.

When it works, this two-way flow of insights and information can be the engine for a "cascade of knowledge" (see Chapter 4). It has also provided justification for formula-based research funding, since the research-extension linkage model benefits from researchers being unhindered by contractual grants and thus able to attend to the problems and issues identified by extension personnel.

Available evidence, however, suggests that claims of the research-extension linkage may be overstated. First, extension programs seem to respond to a different set of national, state, and local priorities than do experiment station-based research programs. This probably results from the extension programs' greater reliance on local and state funding support, which has encouraged a focus by extension on some local and state community needs that have not been emphasized by federally funded agricultural research. The end result is that a large part of the research base for extension programs in community, family, and youth leadership development, other social science issues, and nutrition, diet, and health (representing more than 50 percent of extension program effort and less than 20 percent of experiment station research effort) is likely to come from outside the experiment station and perhaps from outside the land grant university system. Another way to look at the situation is that a significant portion of extension's resources are unlikely to be providing input to the course and direction of experiment station-based science.

THE ROLE OF STUDENTS IN RESEARCH

A variety of students are involved in land grant university research; graduate students have the greatest involvement as part of their training. Masters-level students typically have 2- to 3-year programs, and doctorate-level students invest typically 4+ years. In some fields, the majority of graduate students are from nations other than the United States, which indicates the value placed on graduate training in the United States. Postdoctoral students who usually stay for 2 to 3 years have become a major source of research manpower; they already have considerable training and usually take few classes to they can devote most of their time to research under the guidance of faculty and other scientists.

In sheer numbers, the majority of personnel in research programs are undergraduates. They typically work at minimum wage on a part-time, hourly basis. Although research thus partially supports their education financially, many also become keenly interested in science by such exposure. Many undergraduates also serve as interns or do special research studies. These experiential programs are a growing and valuable contribution of research to undergraduate education. Some undergraduate students and programs are funded directly by USDA, private companies, and nongovernmental organizations. Some research grants mandate that researchers identify ways the work will contribute to both undergraduate and graduate student learning.

Second (and related), the subject-matter focus of university-based extension specialists who are often integrated into disciplinary departments are different than those of most county-based agents. For example, Feller et al. (1984) point out that in the field of human nutrition, the ratio of university-based specialists to county-based agents is low (when compared to the ratio of specialists to agents in production agriculture).

Third, in the past few decades the evolution of the academic reward system has weakened the research-extension link by providing disincentives to researchers to engage in applied research and extension and to administrators to link research and extension responsibilities (Feller et al., 1987).

RECOMMENDATION 4. *The LGCA system and the federal government must revitalize the linkages among teaching, research, and extension. To further this goal, the committee recommends the following.*

- *Federal formula funding for research and extension should be combined into a single allocation to LGCAs for food and agricultural system research and extension, requiring that the use of these combined funds reflect a coordinated effort to link university research and extension in the national interest. (It should be strongly underscored that the intent of this recommendation is not to reduce the importance or destroy the integrity of one function or the other but to encourage their integration.)*
- *It should be required that one-half of the formula funds for research and extension at each institution be directed to fund programs, projects, and activities that integrate teaching, research, and extension, with a special emphasis on inter- and multidisciplinary programs and projects, and the engagement of students on research teams and in extension programs as interns and aides.*

Recommendation 4 does not call for new formula funds, but rather aims to refocus the use of existing formula funds (which currently come from and go to two separate pots) more creatively and in the spirit of the land grant mandate of an integrated tripartite mission of teaching, research, and extension.

The committee believes that to promote flexibility in the allocation of resources to support research and extension infrastructure and staffing needs of high-priority projects, after 5 years, no more than 50 percent of formula-based federal funding should be used to pay tenure-track faculty salaries. Additionally, it is important that—as linkages among teaching, research, and extension are encouraged and enhanced—researchers be allowed and encouraged to take advantage of new and innovative delivery mechanisms and public service outlets; and that extension staff be allowed and encouraged to flexibly access and take advantage of the scientific resources and knowledge base beyond the experiment station.

Recommendation 4 is compatible with the 1995 reorganization of the USDA, which merged the federal Extension Service and the Cooperative State Research Service together to form the Cooperative State Research, Education, and Extension Service. It is recognized, however, that this recommendation may require the restructuring of the administrative responsibilities in some LGCAs. Reevaluation of institutional structure is healthy and, with sufficient advance notice, can be managed responsibly in the interest of stronger programs.

ACCOUNTABILITY AND PRINCIPLES FOR THE USE OF PUBLIC FUNDS

As regards the use of public funds for science and technology projects, good management includes sound mechanisms for assuring integrity, effectiveness, and efficiency. The four mechanisms suggested below complement and enhance each other.

1. *A priority-setting process that incorporates input from a wide variety of stakeholders*. (Priority setting is further discussed in "An Expanded and Inclusive View of the Modern Food and Agricultural System" [p. 21].)
2. *Greater use of competitive mechanisms and peer review for allocating research and extension funds*. (The use of competitive funding mechanisms is discussed in Chapter 4.)
3. *Development of goals and measures that can direct and facilitate evaluations of program performance*.
4. *Development of principles to guide the relative roles of the public and private sector in funding food and agricultural system research and extension*.

Federal grants programs can (some already do) rely on both scientists and nonscientists to assure that funding decisions have taken into account both scientific merit and public priorities. Principles that provide a rationale for the relative role of public and private funds may balance input from research and extension beneficiaries, which some believe may be overly weighted toward short-term or narrowly construed interests. Such principles support public funding of long-term fundamental research considered too unprofitable or risky for private sector investment but that, in the assessment of scientific experts, offers promise. At the same time, allocating public funds to research and extension programs on the basis of competition and peer review further enhances accountability in two fundamental ways: it provides a generally accessible public record of how and why the project or program funds were allocated, and it provides a quality check via review by professionals with the appropriate technical expertise (National Research Council, 1994a, 1995b; National Science Foundation, 1986). Currently, neither of these standards is used nationwide for formula or special (congressionally designated) funding of agricultural research and extension, although individual institutions may adhere to these principles and perform satisfactorily.

A FORMAL MECHANISM FOR INTEGRATING TEACHING, RESEARCH, AND EXTENSION

The committee's proposal that LGCAs direct one-half of federal formula funds received for research and extension toward integration activities stems from several perceived needs and problems:

- Many food and agricultural system problems, such as groundwater pollution, rural development, and food safety are not being adequately addressed. They simply cannot be solved by single investigators; new paradigms developed through multidisciplinary approaches are required.
- Research and extension personnel too often do not communicate with one another sufficiently; thus their collective efforts are correspondingly less productive.
- It is too often perceived that research activities are increasingly irrelevant to the teaching mission of land grant universities. This results in unrealized opportunities for experiential learning in research and extension.
- Integrated activities such as multidisciplinary research are difficult to fund, and mechanisms for rewarding participants are lacking; naturally, talented people currently are reluctant to get involved with such projects.
- Evidence suggests federal formula funding is spent almost entirely on salaries; thus there is little flexibility in using such funds to spawn new and creative initiatives that involve teaching, research, and extension resources.

The proposal has several desirable features:

- It requires little or no additional federal funding, would affect only a small share (on average) of each college's budget, and does not pit one state against another.
- It "jump starts" integration activities in the tradition of Hatch funding for research and Smith-Lever funding for extension.
- It gives administrators a mandate to make changes that are otherwise politically difficult. It gives credibility to multidisciplinary and extension-linked research and makes them less risky for researchers.

Specific implementation procedures, which could involve a phase-in period of 5 years, could be left up to each university. A *partial* exemption might be considered for states or territories and their LGCAs where federal formula funds provide more than 20 percent of the experiment station budget and 30 percent of the extension budget. Additionally, a federal coordinating committee might be set up to minimize duplication of efforts among states and identify opportunities for collaboration.

Performance Goals and Standards

The public increasingly seeks from the scientific community clear statements of goals and measurable standards of performance. This public sentiment is reflected in the Government Performance and Results Act (GPRA) of 1993 (Public Law 103-62), which requires every federal agency to have performance goals and measures for its programs by 1997 for its fiscal 1999 budget submission. The GPRA covers federal science and technology and is therefore applicable to the research, education, and extension grants

programs administered by USDA. As the major recipient of these grants, the LGCA system has a strong interest in working with the federal government to assure that meaningful and workable performance goals and measures are developed.

Applying performance measures to research is exceedingly difficult. According to the National Academy of Sciences report *Allocating Federal Funds for Science and Technology* (1995:p. 27).

> Just as the tyranny of quarterly bottom lines can frustrate long-term corporate planning, so also can science be distorted by simple indicators such as publication counts, citation counts, patent counts, doctorates produced, or user satisfaction ratings. These are useful, but incomplete measures. … It makes sense to track relevant measures, but they cannot supplant the essential element of expert judgment that is the bedrock of quality assessment in research and development.

Measuring the performance of LGCA educational programs—both campus-based and extension—is even more challenging (Warner and Christenson, 1984). For academic and extension programs, many of the simple indicators available for research are lacking. This dearth of readily available indicators of teaching and extension output may have led universities, including land grant universities and colleges of agriculture, to more heavily weight research output in granting tenure and promotions. It is widely perceived that in response to the incentives associated with research output, tenure-track faculty tend to give more weight to their research responsibilities than to teaching or public service.

The committee believes that as USDA and the land grant colleges take up the issue of performance indicators, they have the opportunity to redress this imbalance, particularly for extension (or public service more generally), and also to develop indicators that stress the synergy among research, teaching, and extension. For example, evaluation of an extension program might include an expert assessment of the adequacy of the knowledge base for the program and give high marks to programs that effectively incorporate new science and technology. It might also evaluate how the program incorporates students—for example, as interns—in order to offer experiential learning opportunities and engage students in public service. Other criteria might be whether extension is responsive to market forces (and takes advantage of market opportunities) and is synergistic with respect to the use of resources based in different states.

Additionally, the LGCA system could profit by making itself more open to review of its performance from outside the land grant community. The National Research Council recently published *Research-Doctorate Programs in the United States: Continuity and Change* (National Research Council, 1995c), which ranked doctorate programs in 41 fields at 274 universities. The agricultural sciences were omitted from the study (mostly because they had not been included in the preceding edition of the study). It is important for the national image and accountability of food and agricultural science that it be counted in such prominent quality assessments.

Principles for the Use of Public Funds

Fundamental to public accountability is a well-articulated and justified set of principles or guidelines for public funding of food and agricultural system research and extension. These principles should carefully delineate the relative roles of the public and private sectors. Having these principles in place makes priority-setting more straightforward and assures that public monies are not used for purposes that are well meaning but unnecessary because the private sector will direct its own resources to those ends. Having such principles also provides criteria against which the allocation of public funds can be assessed.

Expenditure of federal funds is justified for research and extension that meets two basic criteria: (1) it addresses national needs and priorities and (2) it is aimed at generating *public goods* Public goods are a class of goods of a "common property" nature, that is, they benefit societal groups but do not provide the means for economic returns to private

individuals or firms. In technical terms derived from the economics literature, a pure public good has two characteristics—(1) "non-rivalry," which means that one person's use of it does not reduce the amount available to others, and (2) "non-excludability," which means that others cannot be prevented from consuming it (Samuelson, 1954). Examples of public goods in the context of the food and agricultural system include

- fundamental knowledge (which may be embodied in agronomic practices);
- environmental quality;
- knowledge about food and product safety risks and protection from undue risk;
- improved dietary health;
- protection against genuine national food security risks; and
- knowledge essential to the accomplishment of public goals such as social equity, economic efficiency, and informed public policy making.

Public support is also justified for research and development that may eventually have commercial application in the national interest but is too costly, uncertain, or otherwise an unlikely focus for private sector investment. This support is justified so long as the anticipated research outcomes would not undermine public good goals. For instance, integrative or adaptive research supporting producers or consumers of commodities representing small markets for agricultural input suppliers (many fruit, vegetable, and specialty crops) might not be conducted, despite anticipated benefits, without public support. The same is true for most fundamental research (and some fundamental technology development); it carries too much uncertainty for private investment.

Figure 2-1 lists conditions that justify public support of food and agricultural system research. In each of the areas identified, public support for research is needed across the

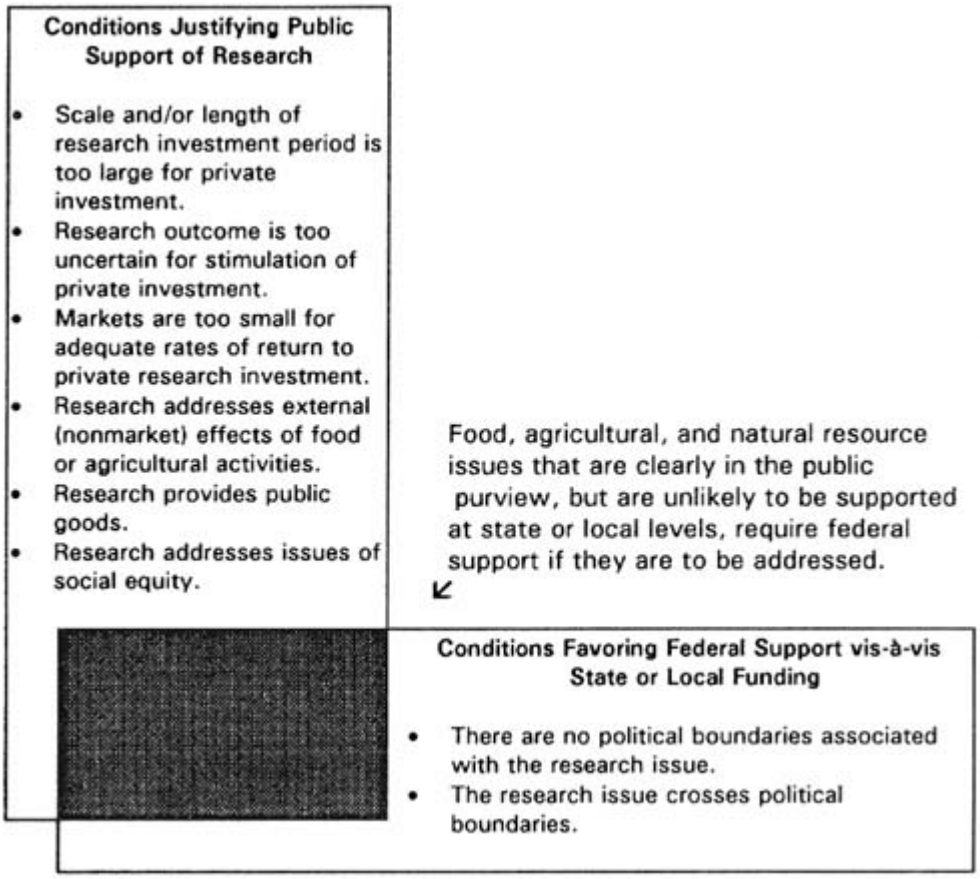

FIGURE 2-1 *Justifying federal support of agricultural research.*

entire spectrum of the research continuum, from fundamental to disseminated research, and encompassing the role of extension at the integrative, adaptive, and dissemination stages.

Federal support is only one element of public support for the U.S. food and agricultural system research. States are presumed to have a particular stake in the support of research that provides public goods within the state (for example, research improving the quality of agriculture-related natural resources unique to and confined within the state) or that differentially improves the welfare of producer groups concentrated within the state but will not be addressed by the private sector. Thus, federal funds for food and agricultural system research and extension should be targeted toward endeavors that meet the criteria for public support but that also provide goods not limited to political boundaries (such as general improvement in nutrition for the increased well-being of citizens) or that cross political boundaries (such as water quality enhancement within a tristate watershed) (Figure 2-1). This suggests, as discussed in "A New Geography and New Partnerships" (p. 30), the unique importance of federally funded regional research and extension programs.

RECOMMENDATION 5. *Regular and critical evaluations of federally funded research and extension programs should assess the congruence between such programs to which federal funds are devoted and the provision or enhancement of public goods of regional and national significance.*

There are several points to emphasize that relate to the use of federal funds to conduct research and extension programs that provide transboundary public goods. First, an allocation based on this principle is broadly consistent with serving the more diverse constituency discussed above. The U.S. public is, in fact, demanding more goods that have these national "public good" characteristics: diet-related health and food safety, sound information about food products, natural resource protection and environmental enhancement, and economic opportunity for small farmers and rural communities (National Research Council, 1995a; Reichelderfer, 1991; Roberts and Smith, 1995). Second, directing federal resources toward the provision of public goods, in an era of constant or declining total federal resources, means redirecting them away from projects and programs that do not meet the criteria. The potential for redirecting public funds is, however, consistent with and significantly enhanced by the larger opportunities for private research in the food and agricultural system. Third, the current priority-setting apparatus has produced priorities consistent with the public goods criteria (see Table 2-1); it is at the output end, in the spirit of the GPRA, where the additional work needs to be done. The Joint Council on Food and Agricultural Sciences reports annually to the Secretary of Agriculture and the U.S. Congress on accomplishments for research, extension, and higher education (see, for example, Joint Council on Food and Agricultural Sciences, 1995). The many accomplishments reported by the Joint Council are indeed noteworthy. However, reporting successes is only a portion of accountability, which also calls for reviewing failures and missed opportunities and developing ideas for continuous improvement.

3

Teaching

This chapter begins with brief summaries of the continuing strong national interest in educating students in food and agricultural sciences and the committee's vision of the federal role in advancing that interest. Some factors involving students and faculty that the committee believes are pertinent to the future of LGCAs—such as diversity and academic preparedness—are discussed in terms of their importance to broadening the client base and enlarging the knowledge base. Also addressed are the challenges that test the strengths and weaknesses of academic programs. The strong interest in developing a collaborative and comprehensive food and agricultural science knowledge base for a diversified clientele—the nation as a whole—presents a unique opportunity for LGCAs. Because LGCAs have a history of success in location- and community-based programs specifically concerned with advancing the knowledge needed to produce the nation's food supply, LGCAs can play a distinctive role in academic programs involving the environmental sciences and systems-based approaches, and that underscore the practical applications of science to modern life.

THE NATIONAL INTEREST IN FOOD AND AGRICULTURAL SYSTEM EDUCATION

The original land grant mandates were intended to provide access to higher education for U.S. citizens of ordinary means and to teach subjects that could help people solve real-world problems and advance economically (Schuh, 1986). In 1862 many of the practical problems to be solved were on farms and in farm households, and a national college system that focused on agriculture and home economics was in keeping with those needs. As land grant colleges expanded into full-fledged universities, they provided access to higher education for people of all income classes and ways of life. The land grant universities generally, and their colleges of agriculture specifically, have raised the level of education of the U.S. citizenry and its agriculturalists. They have contributed importantly to the fact that 18 percent of the total U.S. population 25 years old or older and 17 percent of U.S. farm residents 25 years old or older have completed some college education (Dacquel and Dahmann, 1993).

Access to higher education remains firmly in the national interest, and LGCAs have an important niche to fill in maintaining and expanding access. The national network of

THE LAND GRANT COLLEGES' EARLY YEARS

In 1862 when the first Morrill Act became law, public institutions of higher education were still relatively few and concentrated east of the Mississippi River. Just beginning, however, was another great westward migration that would create settler communities and farms from Kansas City to San Francisco. Federal support for public colleges of agriculture, originally in the form of land grants and later in the form of cash grants, helped assure the westward movement of higher education as well.

In 1862 higher education was largely a privilege of the wealthy. College programs emphasized philosophy, theology, law, medicine, and the classics. Meanwhile, one-half of the country's population lived on farms and more than one-half the labor force worked on them (National Research Council, 1995a). Fortunately, there were those who understood that the nation's economic development would be enhanced by educating farmers and bringing scientific principles to the business of farming. There were also those who saw widespread public access to higher education as essential to a strong democracy. Some scientific schools, industrial schools, and technical agriculture schools had begun to appear by 1862, particularly where agricultural societies were active in pushing for their establishment (Cochrane, 1978). Prior to the Morrill Act, agricultural colleges were established in Michigan, Connecticut (the Yale Scientific School), and Pennsylvania, for example. But a federal role in supporting the development of land grant colleges across the country, on both new and existing campuses, made a major difference in assuring that higher education would be broadly available and would address the practical needs of the nation's food and fiber production system and industrial base.

Establishment of the land grant colleges was not without controversy. Prior to passage of the 1862 Morrill Act, legislators actively debated the federal government's role in public and especially higher education. After the colleges were established, there was the question of their proper teaching mission. There were those who advocated combining the traditional course work with the new—that is, scholarly course work with practical course work (Cochrane, 1979). Within the education community, those who most vigorously fought for federal support of industrial education wanted the colleges to focus on elevating agriculture and mechanical arts to the prestige of the learned professions. Leaders of institutions of higher education, on the other hand, who were mostly classical scholars and preachers, had no interest in such educational goals. Legislators also debated the need for federal funding to achieve the academic program goals.

With continued debate about funding came the realization that a significant segment of U.S. workers, particularly African-Americans, remained underrepresented in the recently created colleges. In 1890 Congress enacted the second Morrill Act, which provided federal funding for 1862 institutions on the condition that access be offered to or, alternatively, that separate institutions be created for African-Americans. Seventeen southern and border states took the latter option and in 1890 authorized the creation of colleges designated for African-Americans. According to Cochrane (1979:p. 243), it took time for colleges of agriculture to fully develop; however,

[b]y 1900 some of the better agricultural colleges had become effective instruments of agricultural education; they had a specialized faculty, a respectable number of students, and some course content in the agricultural disciplines to teach those students. For these colleges the rough, rocky period was past.

public 2- and 4-year colleges, combined with scholarships, grants, student loan, and work-study programs offered by public and private colleges alike, supports access to higher education for most U.S. citizens. Barriers to access are rising, however, despite the fact that returns on higher education for the nation as a whole remain high (U.S. Department of Education, 1995). Tuition increases, entrance requirement modifications, and changes in affirmative action programs all have the potential to affect access for those of limited financial means (Tables 3-1 and 3-2). In this environment and especially because of their unique history, LGCAs have a special commitment to ensuring access. The need for and relevance of the 1890 and, now, the 1994 land grant institutions, along with the bridging programs among 1994, 1890, and 1862 institutions, may well be critical. Without them a significant segment of U.S. society may not receive the education necessary to create maximally productive citizens capable of fully realizing their potential and goals.

It is also profoundly in the national interest to maintain high-quality undergraduate and graduate teaching programs in food and agricultural fields and to draw the best and brightest students into these programs. Today there are relatively few generalist farmers for the colleges to train; however, there are millions of managers, technicians, and consultants, scientists, community leaders, and public servants who on a daily basis confront issues and problems related to the food and agricultural system, which encompasses food and fiber production, processing, marketing, and retailing and the interaction of these activities with the natural environment, human communities, and consumer demands, ethics, health, and safety.

The food and agricultural system needs a highly educated work force that includes scientists, engineers, and technicians. If the world's expanding population is to be fed and clothed at a reasonable cost and without further degradation of the natural resource base or environmental quality, then new and more sustainable ways to produce food and fiber, improve the food distribution system, and enhance food access must continually be sought. Finding new ways to enhance the health and safety of food products also requires educating the next generation of food and agricultural scientists, engineers, and technicians.

The U.S. food and agribusiness sector needs a cadre of top-notch professionals who understand not only science and engineering, but also business, finance, marketing, law and regulation, international markets, and other cultures. Although the colleges' graduate students will continue to find jobs in academia and government, they will increasingly move into private industry (see Table 3-11, p. 54 in the *Profile* report, National Research Council, 1995a; Goeker et al., 1995). These graduates will be tomorrow's internal and external technical consultants in production agriculture, providing technical expertise for vertically integrated food and production systems. This expertise will be the basis of the firm's programs that address environmental issues, food safety, health, value-added technology, efficiency, and marketing. Private actors, such as vertical integrators, will capture this knowledge as part of the value of the corporate entity. Public institutions will also increasingly rely on this knowledge to find ways to manage the interface of production agriculture and a predominately urban and suburban population.

The LGCA system's role in educating graduate students from other countries is also in the national interest. The *Profile* report (Table 3-5, pp. 44–45) notes that foreign students composed more than one-quarter of all graduate students at LGCAs in 1993. These students—in addition to being important customers of the U.S. university system—have the potential to make important contributions during their careers to the continuing ability of the global food and agricultural system to meet the needs and demands of a still rapidly expanding global population. The U.S. food and agricultural system cannot be insulated from developments at the international level. Inadequacies of the global food and agricultural system will be reflected in higher U.S. food prices, lower real income for U.S. consumers, and more severe pressures on the nation's natural resource base.

Finally, food and agricultural systems education that is accessible and relevant to the university students generally is important to building a solid base of public understanding

TABLE 3-1 Tuition and Fees at 1862 Institutions, 1992–1994

Institution	Tuition and Fees		Added Out-of-State Tuition,
	1992–1993	1993–1994	1993–1994
Auburn University	1,755	1,950	3,900
University of Alaska, Fairbanks	1,870	2,214	3,328
University of Arizona	1,590	1,844	5,506
University of Arkansas, Fayetteville	1,838	2,036	3,024
University of California, Berkeley	2,919	3,968	7,699
University of California, Davis	2,980	3,712	7,699
University of California, Riverside	2,923	3,750	7,701
Colorado State University	2,510	2,566	5,626
University of Connecticut	3,902	4,290	7,120
University of Delaware	3,721	3,948	6,100
University of the District of Columbia	800	974	2,592
University of Florida	1,649	1,697	4,902
University of Georgia	2,175	2,250	1,845
University of Hawaii, Manoa	1,437	1,868	3,570
University of Idaho	1,296	1,426	3,900
Univ. of Illinois, Urbana-Champaign	3,328	3,388	4,252
Purdue University	2,144	2,310	3,294
Iowa State University	2,228	2,352	5,030
Kansas State University	1,841	1,960	4,618
University of Kentucky	1,904	2,278	3,920
Louisiana State University	2,170	2,628	3,300
University of Maine	3,086	3,406	5,400
University of Maryland, College Park	2,778	3,179	5,604
University of Massachusetts, Amherst	4,799	5,467	6,346
Michigan State University	4,277	4,277	6,360
University of Minnesota	3,158	3,266	5,588
Mississippi State University	2,473	2,473	2,460
University of Missouri, Columbia	2,812	3,125	5,076
Montana State University	1,839	2,002	3,892
University of Nebraska, Lincoln	2,188	2,462	3,360
University of Nevada, Reno	1,650	1,665	4,300
University of New Hampshire	3,941	4,096	7,630
Rutgers University, Cook College	4,375	4,743	3,943
New Mexico State University	1,756	1,872	4,200
Cornell University	7,000	7,370	6,680
North Carolina State University	1,302	1,389	7,042
North Dakota State University	2,033	2,219	3,314
Ohio State University, Columbus	2,799	2,940	5,931
Oklahoma State University	1,802	1,800	3,204
Oregon State University	2,691	2,877	5,097
Pennsylvania State University	4,618	4,822	5,348
University of Rhode Island	3,540	3,882	6,724
Clemson University	2,762	2,954	4,942
South Dakota State University	2,030	2,130	1,839
University of Tennessee Knoxville	1,898	1,982	3,780
Texas A&M University	1,465	1,526	4,080
Utah State University	1,776	1,878	3,645
University of Vermont	6,150	6,380	8,944
Virginia Polytechnic Institute and State University	3,538	3,812	5,868
Washington State University	2,274	2,532	4,602
West Virginia University	1,928	2,026	3,844
University of Wisconsin, Madison	2,344	2,538	5,863
University of Wyoming	1,430	1,698	3,534
University of Puerto Rico, Mayaguez	970	970	0

SOURCE: Food and Agricultural Education Information System (FAEIS).

TABLE 3-2 Tuition and Fees at 1890 Institutions, 1992–1994

Institution	Tuition and Fees		Added Out-of-State Tuition,
	1992–1993	1993–1994	1993–1994
Alabama A&M University	1,550	1,550	1,600
Tuskegee University	6,535	6,735	0
University of Arkansas, Pine Bluff	1,594	1,624	1,920
Delaware State College	1,788	1,966	3,032
Florida A&M University	1,751	1,829	4,902
Fort Valley State College	1,722	1,779	1,380
Southern University A&M College	1,588	2,028	1,922
University of Maryland, Eastern Shore	2,450	2,674	4,727
Alcorn State University	2,376	2,376	2,142
Lincoln University	1,498	1,820	1,800
North Carolina A&T State University	1,270	1,367	6,066
Langston University	1,419	1,505	2,070
South Carolina State University	2,200	2,500	2,480
Tennessee State University	1,632	1,706	3,782
Prairie View A&M University	1,535	1,568	4,080
Virginia State University	2,913	3,050	3,674

SOURCE: Food and Agricultural Education Information System (FAEIS).

regarding food and agricultural system issues. The issues surrounding food and agriculture epitomize the complex and challenging choices that modern society must make. They involve all citizens of all income classes, ethnicities, and cultural backgrounds in all parts of the country. Thus, there is a national interest in education that produces well-informed, effective, and diverse citizen participation in public policy related to food and agriculture.

In sum, the teaching component of the LGCA's mission is like the base of the pyramid: without it the sides are not supported. Academic programs train the system's scientists, extension specialists and agents, its users and clientele, and its teachers.

THE FEDERAL ROLE

The original impetus for land grant legislation was the need for higher education for the majority of U.S. citizens; however, financial support for the teaching component of land grant education has since been largely delegated to states. The federal government has placed its priority on the advancement of science and agriculture through the funding of research and the dissemination of research-based knowledge through extension programs. In 1995 USDA allocated $406 million to universities and colleges for research and development (R&D), $439 million for extension programs, and $18 million for higher education grants (of which more than one-half were for institution capacity building in both teaching and research at the 1890s). The difference between $845 million for research and extension and $18 million for higher education suggests that federal support for food and agricultural systems may be relatively research intensive. In 1991 USDA contributed 4.1 percent of all federal R&D to universities and colleges, whereas it contributed only 2.3 percent of all federal grants for higher education fellowships and traineeships. Furthermore, the federal government no longer allocates grants to states specifically for teaching programs at the 1862 land grant colleges, although it continues to fund block grants to states for their state agricultural experiment stations and cooperative extension programs (programs based at land grant colleges of agriculture and employing college faculty). Morrill-Nelson grants were provided to states ($50,000 per state) until recently to support land grant teaching programs; however, these monies were merged in recent years with institution "challenge grants." Challenge grants, which are broadly

THE DEMAND FOR COLLEGE GRADUATES IN FOOD AND AGRICULTURE-RELATED FIELDS

A recent study supported by USDA and published by Purdue University (Goeker et al., 1995) projects average annual employment opportunities of 47,918 positions during 1995–2000 for college graduates with expertise in food and agriculture-related fields. A comparison with estimates for available graduates in food and agricultural sciences (25,287) and in allied fields (20,388) reveals a projected shortfall of 3.7 percent each year. Despite the shortfall, the report notes that the job market is more competitive than in the early 1990s. Higher enrollments at colleges of agriculture is one reason. Another is the increased competition from graduates in allied fields who are capable of competing with food and agricultural science graduates for the same positions.

Nearly three-quarters of the total projected shortage is in the marketing, merchandising, and sales employment cluster. Strong opportunities are forecast for graduates having scientific and technical expertise in developing new consumer products from raw agricultural and forest materials; in food quality control and food safety operations; and for those with expertise in managing water, land, and other natural resources used in the food and agricultural system. In contrast, the report projects declining opportunities for farm and ranch owner-operators, and a surplus of qualified graduates. Production management opportunities continue to expand, but graduates must have increasingly specialized skills and experiences with a particular species or a distinct phase of the production process.

available to academic institutions, support food and agricultural sciences teaching programs through curricula enrichment, faculty development, expansion of experiential learning opportunities, and the promotion of new technologies for instruction delivery systems (National Association of State Universities and Land Grant Colleges, 1995).

The strong national interest in a diverse and well-trained food and agricultural work force implies that the federal government should have a continuing and strong role in enhancing access to and participation in food and agricultural systems education, and in recognizing and stimulating innovation in curricula that orients higher education toward the needs of the modern food and agricultural system. The federal government's role in funding the teaching programs at LGCAs and their students is limited, however, by budget realities. It is therefore even more important for the federal government to be an effective and important catalyst because it cannot be a checkbook. The Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), the precursor to the current National Science and Technology Council, has described the role for the federal government in higher education as one that highlights national challenges, mobilizes national support, and funds programs that offer unique solutions.

Although the federal government's role in higher education grants for food and agricultural education may be limited, the federal contribution to higher education can be enhanced by stressing and encouraging the teaching opportunities inherent in research and extension programs. Research grants programs should encourage the participation of undergraduates on research teams, and extension grants programs should encourage the participation of both graduate and undergraduate students in public service and other extension activities.

USDA-ADMINISTERED HIGHER EDUCATION GRANTS

The President's request for FY 96 reduces funding for institutional challenge grants and requests $1.5 million for Hispanic Education partnership Grants and $4.6 Million for the Native American Endowment Fund. The FY 95 appropriations are as follows:

Grant Type	Amount
Institution Challenge Grants	$4,350,000
Multicultural Scholars Program	$1,000,000
1890 Capacity Building Grants	$9,207,000
Graduate Fellowship Grants	$3,500,000

- Institution Challenge Grants provide competitive grants to colleges and universities to enhance food and agricultural sciences teaching programs. Methods of enhancement include enriching curricula; promoting faculty development; expanding experiential learning opportunities of undergraduates; and using new technologies for enhanced instruction delivery systems. Supported projects address regional, national, and international higher education issues; involve creative and novel approaches to teaching that can serve as models for the whole system; foster partnership initiatives across the university science and education community, as well as between universities and the private sector; and generate additional support to augment that provided by USDA.
- The Multicultural Scholars Program provides the opportunity for 1862 land grant schools to reach out specifically to ethnic minority students to enhance minority participation in food, agricultural, and natural resource science education.
- 1890 Capacity Building Grants, in conjunction with the Multicultural Scholars Program, help the LGCA system to
- —strengthen linkages between institutions whose primary clientele has historically been members of ethnic minorities and other institutions—colleges and universities, USDA, and private industry;
- —advance cultural diversity of the food and agricultural scientific and professional work force by attracting and educating more minority students; and
- —enhance the quality of teaching and research programs at the 1890 institutions.
- Initiated in 1984, Graduate Fellowship Grants are targeted specifically to the recruitment and education of predoctoral students for critical food and agricultural science positions in areas identified as having a "shortage of expertise." During the period FY 1984–1993, a total of 722 fellows were supported through 273 grants awarded to 51 institutions in 38 states.

SOURCE: National Association of State Universities and Land Grant Colleges. 1995. The Unique Land Grant System Working for People, Food, Agriculture, Environment through Teaching, Research, and Extension, March 1995.

CHARACTERISTICS OF STUDENTS, FACULTY, AND ACADEMIC PROGRAMS

Students

LGCAs must continue to seek creative ways to capture the interest and imagination of talented students who have little or no connection to farming. Many students simply have no idea that agricultural practice and agricultural science still contain the excitement of continuous discovery as well as the fascination of state-of-the-art technological applications. The development of the transgenic animal, the testing and marketing of genetically engineered plants, and the use of remote sensing and tractor-mounted computers to guide farmers' applications of nutrients and pesticides are all part of today's agriculture. However, as Handelsman (1992: p. 199) writes,

> … agriculture as a field of study is dogged by conservative, dusty, and dull images. It is regarded as a field of old-fashioned science and traditional technology practiced with wanton disregard for the environment. Sadly, students in our universities are more likely to associate agriculture with pictures of dark-suited, austere, nineteenth-century professors and one-horse plows than with casually dressed, twentieth century molecular biologists and computer terminals.

Although this image is changing, it still lags too far behind modern realities and undermines attempts to attract students to majors in agriculture and non-LGCA students to the general studies courses in food and agricultural systems. At the LGCAs, those who are responsible for developing public perceptions must strive to understand the factors that have shaped student perceptions and continue to narrow the gap between image and reality.

It will be necessary to improve the image of LGCAs to attract top students at both the undergraduate and graduate levels. In recent years, on average, standardized test scores for students intending to enroll in agricultural programs have been relatively low. (Data are not available to analyze average standardized test scores of students already enrolled at LGCAs; and these average scores likely differ significantly among individual colleges.) Although tremendous care must be taken in interpreting scores, colleges and their federal partners in higher education should closely monitor and assess such indicators as signs of academic preparedness, and more effort should be made to understand why potential agriculture majors score relatively low. In 1994 the combined verbal and quantitative Standard Achievement Test (SAT) scores of college-bound seniors intending to major in agriculture and natural resources were approximately 5 percent lower than the average combined score for all students. Among average scores for 23 disciplines, students intending to major in agriculture or natural resource disciplines ranked 16th in verbal scores and 19th in mathematics. Students planning to major in physical sciences and language and literature had combined verbal and mathematics average scores 19 percent and 18 percent, respectively, higher than those of prospective agriculture and natural resource majors. Students intending to major in social sciences and history had combined average scores more than 9 percent higher than those students intending to study agriculture and natural resources (U.S. Department of Education, 1995).

A similar picture emerges from average Graduate Record Examination (GRE) scores. Students intending to go to graduate school in biological sciences, computer sciences, physical sciences, economics, engineering, mathematics, physics, and astronomy had higher scores on average on verbal, quantitative, and analytical sections than did students intending to go to graduate school in agricultural fields—that is, agricultural economics, agricultural production, agricultural sciences, agronomy, animal sciences, fishery sciences, food sciences, forestry and related sciences, horticulture, parks and recreation management, plant sciences except agronomy, renewable natural resources, resource management, soil sciences, wildlife management, and agriculture—other (Educational Testing Service, 1995) (Table 3-3). Because the food and agricultural industry increasingly draws its employees from the allied or related fields, such as business, engineering, chemistry, biology, and health sciences, it is especially important that students with a special interest in food and agriculture—an interest strong enough to declare majors in food and agricultural fields specifically—can indeed compete.

TABLE 3-3 Graduate Record Examination: Average of Verbal, Quantitative, and Analytical Scores, 1991–1994

Intended Field of Graduate Study	Approximate Number of Intended Majors	Average Mean	Average Standard Deviation
Life sciences	95,110	522	111
Agriculture	7,493	526	107
Biological sciences	31,619	563	111
Health and medical sciences	55,998	499	104
Physical and mathematical sciences	43,956	595	117
Engineering	54,652	590	109
Social sciences	104,664	525	117
Humanities and arts	59,041	553	116
Education	39,176	494	111
Business	7,692	509	122
Other fields	53,569	nc	nc

NOTE: Data are based on the performance of seniors and non-enrolled college graduates who tested between October 1, 1991, and September 30, 1994. The table does not include summary information about the approximately 55,900 examinees whose response to the department code question was invalid or the approximately 82,450 examinees whose response was "undecided." nc, not calculated.
SOURCE: GRE 1995-96 Guide to the use of the Graduate Record Examination Program, published for the Graduate Record Examinations Board by Educational Testing Service.

Accessibility and Relevance to Precollege Students

Land grant colleges have had a close connection traditionally to the nation's rural youth. Many college of agriculture undergraduates have been recruited through 4-H and high school vocational agriculture classes, programs traditionally more prominent in rural areas. In some parts of the country, rural high schools are less well-equipped to prepare students to meet college entrance requirements, such as in foreign languages. Data also suggest that rural high school students may be generally less-oriented toward college and advanced degrees than nonrural students (Stern, 1994). The committee believes LGCAs should use and further develop their connections with the precollege public school systems to ensure that rural high school teachers, student advisers, and students know about college and university entrance requirements and that young people understand the benefits of a college degree and are aware of their college opportunities.

Urban and suburban settings, however, are where most of the country's youth now are located, and they are less well connected to agriculture-oriented youth programs such as 4-H Clubs. Colleges of agriculture must refocus their mentorship and recruitment efforts to include traditional youth organizations in urban and suburban settings such as the Boys and Girls Clubs and Girls, Inc. A stronger presence on the part of appropriate land grant college faculty in K-12 classrooms in urban and suburban as well as rural areas could be of significant benefit to students, faculty, and the college. Using food, fiber, and environmental resources, and agriculture's connection to them, offers an excellent way to introduce scientific concepts and principles and to make them relevant to the daily lives of students. An introduction to food and agricultural systems and issues in K-12 classrooms can be an important way to attract urban and suburban students to study in food and agricultural disciplines. Also, devoting time to precollege education helps enhance the preparedness of potential students, while providing a meaningful service contribution by LGCA faculty.

GIS TRAINING AT LINCOLN UNIVERSITY

Geographic information systems (GISs)—computer-based technology used to layer and integrate spatial data from many sources—have important and growing applications in the food and agricultural sciences. For example, information from a GIS that integrates data such as soil type, moisture level, slope, and temperature at each field site allows farmers to make more precise management decisions—for example, optimal concentrations and amounts of pesticide and fertilizer applications (hence, "precision farming"). GISs have many applications in natural resource management, and some land grant schools are taking the lead in developing programs and careers in this technology. For example, Lincoln University in Jefferson City, Missouri, has a Center of Excellence for Leadership in GIS and Wildlife Management. The center offers students course work and laboratory exercises in GIS and remote sensing, particularly oriented toward wildlife management; it offers regional training short courses for government agencies and private industry; and it has undertaken projects for USDA, the Missouri Department of Conservation, and the U.S. Fish and Wildlife Service, such as an assessment of landscape changes along the Missouri River resulting from the 1993 flood. The Center of Excellence Initiative is a partnership between Lincoln University and the U.S. Department of Agriculture.

Accessibility and Relevance to a Diverse Set of Students

The colleges of agriculture are finding it difficult to recruit and retain significant numbers of students from racial and ethnic minority groups. The nation will be ever more culturally diverse in the years ahead. In fact, people of color, women, and immigrants will account for more than five-sixths of net additions to the work force by the year 2000 (Johnston and Packer, 1987), and agricultural industries need and desire a diverse work force that reflects the international scope of their business (Wall Street Journal, 1995). This constitutes a major challenge since students from ethnic minority groups represented only 10 percent of LGCA enrollment in 1993, up from 5 percent in 1984. As a point of contrast, these students represented 20 percent of all higher education enrollment (U.S. Department of Education, 1993).

In 1993 women composed 39 percent of undergraduate enrollment and 35 percent of graduate student enrollment at LGCAs; this contrasted with 36 percent and 28 percent, respectively, in 1984. However, as reported in the *Profile* report, women are significantly better represented in "other" degree programs—including any nonagricultural program offered by the college—than they are in the traditional "agricultural" fields (National Research Council, 1995a). It is also the case that the percentages of women in life and natural sciences and other university programs is higher than in agriculture. At all U.S. institutions of higher education (surveyed) more than one-half of both graduate and undergraduate students are women (U.S. Department of Education, 1993).

The 1890 institutions—the traditionally Black LGCAs—have played a significant role in training students from various ethnic minorities in agricultural and food sciences, engineering, mathematics, and other disciplines. In 1993 about 20 percent of minority students pursuing bachelors' degrees in agriculture and natural resource specializations were enrolled at 1890s colleges (National Research Council, 1995a). Students will continue to access these institutions, attracted by the nurturing environment, the presence of

minority faculty in leadership positions who can serve as role models, and the quality of the academic programs (LeBlanc, 1996).[1] However, the second Morrill Act did not endow the 1890 institutions with the resources appropriated for 1862s, and they were not compensated in subsequent legislation. For example, the Morrill-Nelson grants, which provided $50,000 annually to each state for land grant academic programs, were not accessible to the 1890s for many years (and even then some received only minimal amounts). Compensatory efforts have been made through capacity building programs (initiated in 1988), designed to enable these institutions to meet the needs of expanding student populations.

Twenty-nine Native American tribal colleges have recently achieved land grant status as a provision of the 1994 Elementary and Secondary Reauthorization Act. Located in 12 states, most of these institutions are 2-year and technical schools, but three are 4-year institutions and one offers a master's degree. The schools have been quite successful at providing educational opportunities to Native American and other students as well as providing important services to Native American communities, in keeping with the land grant tradition and philosophy of providing educational access and opportunity where it is needed (Campbell, 1995).

The LGCAs have a unique opportunity to assure access through the institutional linkages among the 1862, 1890, and now, the 1994 land grant institutions. The committee believes that because of their shared legacy, LGCAs should (and many do) have a commitment to facilitating access to 1862s by students at 1890 and 1994 land grants. This can be done by brokering articulation agreements between the sets of institutions that facilitate student and faculty exchanges, such as the Academic Common Market of the Southern Regional Education Board; and by establishing "2+2+2" programs to assist students in moving from the last 2 years of high school into a 2-year college program and then on to a 4-year school.

RECOMMENDATION 6. *The bridging programs among 1862s, 1890s, and 1994s deserve special emphasis from federal funding programs, such as federal challenge grants, including evaluation of their effectiveness as models for expanding access and diversity in the food and agricultural sciences. The federal government should also become an active promoter of the use of articulation agreements among institutions within and across states to facilitate student exchanges and transfers, and encourage collaborative internship programs among institutions in the LGCA system.* (Also see Recommendation 3.)

There are also unexploited possibilities for integrating the institutions' teaching programs. Many 1862 and 1890 land grants are not far from each other geographically; yet their students and faculty interact relatively little. There are numerous possibilities for designing courses jointly taught by 1862 and 1890 faculty, thereby enriching the diversity of backgrounds and views in the classroom as well as enhancing access.

Faculty

The characteristics of the faculty of land grant colleges can be extremely important to the colleges' ability to attract students. Data about demographic characteristics of agricultural scientists holding doctorate degrees suggest they are slightly older on average than their peers in life and natural sciences, which is because the ranks of agricultural scientists are being replenished at a slower rate (National Research Council, 1995a). Women, although increasingly well represented, are still, substantially, a minority on the faculties of many agricultural colleges; and members of ethnic minorities are uncommon

[1] *A Common Destiny: Blacks and American Society* (National Research Council, 1989c) cites several studies that find African-American students on white campuses frequently express feelings of alienation and social isolation; luke-warm relationships with white students, faculty, and staff; and little engagement in campus activities.

SOUTH DAKOTA STATE UNIVERSITY'S "2+2+2" PROGRAM WITH RESERVATION HIGH SCHOOLS AND TRIBAL COLLEGES

The highest incidence of poverty, unemployment, and fetal alcohol syndrome in the United States is on Native American reservations in South Dakota. In addition, average education levels attained among Native Americans in South Dakota are very low. Despite composing approximately 10 percent of the state's population, Native American enrollment in postsecondary institutions is less than 1 percent.

To address this problem, South Dakota State University (SDSU) has developed a collaborative system whereby the SDSU's colleges of Agriculture and Biological Sciences as well as Home Economics will increase their collaborative efforts with reservation high schools and members of the American Indian Higher Education Consortium (AIHEC). Interaction and collaboration among institutional academic programs will facilitate Native Americans' progression from high school to completion of baccalaureate degrees through integration into the work force. Cohesive transition through each step of the process is supported by partnerships between institutions, and efforts are focused on curricula during the last 2 years of reservation high school, followed by 2 years in AIHEC schools, and a final 2 years at SDSU.

The objectives of this "2+2+2" system include developing course-by-course articulation between all participating institutions; refining current SDSU courses and degree options in agriculture and home economics to better meet the needs of Native Americans; securing and using technology as a means for expanding SDSU's ability to reach Native Americans with programs in agriculture, natural resources and family and consumer sciences; supporting experiential learning opportunities for Native Americans; and building a support system that motivates, supports, and empowers students through completion of their degrees. Faculty development to meet the needs of the students is designed to ensure that 2-year curricula from all schools complement the others.

Although expanding access to higher education is the primary goal, graduates of the program will be prepared to return to their reservations and address some of the key issues facing their communities. With more Native American professionals in agriculture and natural resources, management of land and natural resources will improve, which in turn will improve reservation economic viability. As more Native Americans enter family and consumer sciences, the result will be an enrichment of the quality of family and community well-being. Greater trust and better working relationships between Native Americans and non-Native Americans will ultimately occur as a result of collaborative endeavors among educational establishments.

on the faculties of 1862 LGCAs. An increasingly diverse student body is, of course, the most important means toward a more diverse faculty. Expanding and diversifying enrollments in colleges of agriculture is the most important means of regenerating and diversifying the faculty ranks, so that the colleges can meet the teaching and research challenges of today and tomorrow.

Faculty-Student Contact and Teaching Incentives

The public is particularly concerned about the university's commitment to teaching (Greenwood, 1995). The Center for Instructional Development at Syracuse University conducted a study and found that university faculty and university administrators share the view that their institution favors research over teaching. However, each of these groups thinks that members of the other group also favor research over teaching. As regards the general public, the results of a 1995 survey of adults in the 48 contiguous states finds that a majority of respondents think undergraduate teaching, graduate teaching, off-campus extension, continuing education, and research are all "very important" responsibilities of their states' land grant universities. However, a significantly higher percentage of respondents ranked teaching "very important" (in relation to the percent of respondents that ranked the other activities "very important"). Also, when told to imagine that they had $100 of taxpayer money to spend, respondents allocated $45 to teaching students on campus, $30 to off-campus education and technical help, and $25 to doing research (Dillman et al., 1995).

Most land grant colleges of agriculture have a unique advantage vis-à-vis other colleges and units of the university with respect to their ability to devote faculty resources to students. Formula funding has allowed many colleges of agriculture to maintain a relatively high faculty-student ratio. In fact, in the *Profile* report [see Tables 3-1 (p. 38) and 4-3 (p. 61)] it is noted that USDA-administered grants account for slightly less than 5 percent of all federal R&D dollars allocated to extramural research at universities and colleges; at the same time that LGCAs—the main recipients of those grants—enroll approximately 1 to 2 percent of all undergraduate and graduate students nationwide (National Research Council, 1995a). This suggests that on average there are more faculty in relation to students, although not all faculty have explicit responsibilities for student advising or teaching. Thus, colleges of agriculture are in a particularly strong position to commit to students. In some parts of the country, students continue to be drawn to colleges of agriculture through their contacts with cooperative extension agents in their communities, which means that the colleges' ties to their students (especially those from farm and rural backgrounds) and their families may be particularly strong, which creates a nurturing environment for this group of students. Today, however, LGCAs must connect with communities in rural, urban, and suburban settings to recruit students and diversify their student bodies. Participating in K-12 science education projects and involving more college faculty in urban-based extension programs are suggested ways to build the needed bridges.

Although colleges of agriculture may have opportunities to devote relatively more faculty resources to each student, college of agriculture faculty, like their counterparts in other colleges, perceive that the rewards are in research, which, as was noted in Chapter 2, is where federal funding is concentrated. Some college of agriculture faculty feel disadvantaged in the tenure and reward process at the university level because of their explicit responsibilities for extension as well as teaching and research. The tenure and reward system is an issue that transcends colleges of agriculture and land grant universities; indeed, this issue has captured the attention of all higher education nationally. Colleges of agriculture have a special interest in and the potential to shape the outcome. For example, in 1995 Oregon State University adopted revised guidelines for promotion and tenure that drew from concepts developed initially by the university's College of Agricultural Sciences. The guidelines rest on a more broadly defined concept of scholarship as creative intellectual work that is validated by peers and communicated. The

guidelines recognize, among other things, teaching, research, and extended education as vital university missions and faculty activities that are not scholarship in themselves but that can each involve creative, communicated, peer-validated intellectual work (scholarship) in any of its several forms (discovery, development, integration, artistry) (Weiser, 1996) (see Figure 3-1).

Academic Programs

Resources and data necessary to thoroughly and adequately assess changes in curricula content and design across the LGCA system were not available to the committee; however, creating more innovative academic program content and teaching methods recently has been of interest and a focus of colleges of agriculture (Kunkel et al., 1996). Greater diversity among college curricula and their goals is replacing the widely standardized curriculum of earlier decades, which emphasized development of the specialist in production agriculture. Students in many contemporary colleges of agriculture have shifted to biochemistry and genetics, agricultural business and management, nutrition, or natural resources. There is greater appreciation of the need for economics, management, and preparation for the international workplace. Colleges are responding to critics and developing courses that address issues of sustainability and stewardship of the environment; and ethics and social policy are increasingly elements of the colleges' courses (Townsend and Kunkel, 1996). Some examples of efforts to innovate curricula are reported by Kunkel and Thompson (1996), who discuss specific developments at Rutger University's Cook College, Cornell University, Texas A&M University, the University of California at Berkeley, the University of Illinois, and the Ohio State University.

There are major trends and forces reshaping the educational needs of the food and agricultural system. One is the increasing sophistication of farming and ranching as managerial activities requiring large amounts of increasingly technical information. Agriculture

The Nature of Scholarship

Scholarship is creative intellectual work that is validated by peers and communicated. Forms of scholarship include discovery, development, integration, and artistry.

Forms	Discovery	Development	Integration	Artistry
Character of scholarship	Generates, synthesizes, interprets, and communicates new knowledge, methods, understandings, technologies, materials, uses, insights, beauty, . .			
Audiences for scholarship	Peers, students, users, patrons, publics, . . .			
Means of communicating scholarship	Publications, presentation, exhibits, performances, patents, copyrights, distributions of materials or programs			
Criteria for scholarship	Accuracy, replicability, originality, scope, significance, breadth, depth and duration of influence, impact or public benefit, . . .			
Means of documenting scholarship	Present evidence that creative intellectual work was validated by peers; communicated to peers and broader audiences; recognized, accepted, cited, adopted, or used by others; . . . that it made a difference.			

FIGURE 3-1 *Forms of scholarship. Source: Reprinted courtesy of Conrad J. Weiser and Oregon State University.*

production is becoming much more precision oriented and biologically and managerially intensive, requiring an understanding of physical and biological processes and their site-specific interactions. This places significant demands on the science curricula in colleges of agriculture and on the way science is taught. The colleges of agriculture have the potential to be leaders in developing and teaching multidisciplinary systems-based approaches that can greatly enhance student understanding of the practical applications of the disciplinary sciences and their preparedness for food and agricultural careers.

A second major trend is consumer concern about the safety of foods coupled with a better understanding of the link between food characteristics, nutrition, and health. Agricultural education must put an increasing emphasis on food and nutritional sciences and produce graduates who not only understand but can also enhance the linkages among crop and livestock genotypes, production practices, food processing, and consumer health.

A third trend is globalization of the agricultural industry. For decades large grain companies have operated from a U.S. base in the global marketplace. Increasingly, U.S.-based companies must also be competitive in global markets for consumer and value-added products based on agricultural ingredients. This requires an advanced level of cultural, social, and political knowledge that has relatively recently begun to characterize U.S. agribusiness and also has significant implications for education of agricultural professionals (Goodman, 1992). The committee believes many colleges of agriculture have recognized the need to offer their students a global perspective and a good grasp of international markets and cultures. Many colleges have made significant strides in curriculum development in international agricultural markets and trade and in offering students international work-study opportunities. Some continue, however, to grapple with international studies issues as fundamental as foreign language requirements.

A fourth trend is industrialization of the food and agricultural system. Although the range of skills and expertise needed in the vertically integrated firm is extreme, individual managers and technicians must have highly specialized skills that relate to a particular phase of the production, processing, and marketing continuum. Colleges of agriculture need continuing input from industry to ensure that their curricula provide the knowledge base for these specialized skills and positions.

Problem-Solving Orientation

Over the decades, as the agricultural disciplines matured, the colleges organized their programs around disciplinary departments and strengthened the theoretical and basic science content of their courses. Reflecting this trend, many colleges changed their names from "college of agriculture" to "college of agricultural sciences." This trend was probably reinforced by criticisms of the colleges' programs by the science community. In 1972 and again in 1982, two reports by independent scientific committees (National Research Council, 1972; Rockefeller Foundation, 1982) faulted the land grants for placing too much emphasis on applied research on local problems and not enough on basic biological research.

Today the system's historical commitment to practical education may be best seen in the emphasis on student internships in industry. The 1995 forums the committee conducted at selected land grant colleges revealed both student and industry satisfaction with the colleges' emphases on internships and with the link between education and the real world that internships provide. However, the colleges' commitments to (or resources for) internships with organizations less closely associated traditionally with the colleges of agriculture, such as food banks, community service organizations, nutrition programs, public interest and nonprofit entities, or public agencies with natural resource or environmental responsibilities, are less developed and should be expanded. Graduate students need this kind of experiential opportunity and exposure as much as undergraduates.

CURRICULUM REVITALIZATION PROJECTS

In the late 1980s the W. K. Kellogg Foundation funded an initiative, Project Sunrise, to revitalize curricula at land grant colleges of agriculture on the campuses of University of Minnesota, University of Nebraska, and University of Wisconsin. At each of the colleges, innovations led to both new methods of teaching and learning and new curriculum content.

At the University of Minnesota the project resulted in intensive faculty development in alternative learning strategies, such as cooperative learning, for teaching critical thinking, problems solving, and decision making. Ten new college and intercollegiate majors—including agribusiness management, agricultural education, agricultural industries and marketing, animal and plant systems, applied economics, food science, natural resources and environmental studies, nutrition, science in agriculture, and scientific and technical communications—reduced the number of majors and were designed to give focus to undergraduate education across departments.

The University of Nebraska project led to changing the College of Agriculture's name to the College of Agricultural Sciences and Natural Resources. New general education requirements were developed that emphasized writing and communication and that met the test of new university-wide requirements. Case studies and computer simulations, as well as other new teaching and learning methods were introduced. New courses were established, including ethics in agriculture and natural resources, science of food, biological systems engineering, and quality of the environment. New programs of study included environmental studies, natural resources majors, and landscape architecture.

The University of Wisconsin's assessment of its curriculum led to, among other things, mini-grants to fund revitalization of courses and introduce new teaching strategies. Among the curriculum innovations was the development of an agriculture, technology, and society program that included 11 new courses and 2 existing courses and the development of a an interdisciplinary course for incoming students called "An Orientation to the College of Agricultural and Life Sciences." The faculty improved their computer skills, audiotapes were developed and distributed to introduce faculty to the learning styles of "nontraditional" students, and videotapes were developed on how to cope with academic stress.

Among the lessons learned through Project Sunrise were the need for involving faculty in, and building faculty commitment to, change; the need for faculty development; the need for openness and communication regarding outcomes; and the need for flexibility in curricular designs and methods of operation so that adjustments can be made and tested easily.

Source: Povlacs Lunde, J., M. Baker, F. H. Buelow, L. Schultz Hayes. 1996. Reshaping Curricula: Revitalization Programs at Three Land Grant Universities. Bolton, Mass.: Anker Publishing.

RECOMMENDATION 7. *The colleges of agriculture should require students to take at least one internship from a wide range of creative, mentored internship opportunities representing the diverse career settings for which graduates in food and agricultural sciences are prepared.*

Broader use of extension internships as credited programs could be an avenue to accessing these opportunities. The colleges should work with their cooperative education programs to diversify internships for agriculture majors and to open traditional agricultural internships to students not majoring in agriculture. It is hoped that state and federal agencies and private enterprises directly or indirectly engaged in the food and agricultural system will initiate and welcome partnerships with LGCAs to provide meaningful internships for students and financial support for these programs.

"Hands-on" experience in class is another way that innovative colleges link theory and practice and thereby offer problem-solving skills to their students. Many examples drawn from traditional production courses may be found, but most important is the evidence that the "hands-on" concept has begun to be incorporated into newer courses. For example, the University of Florida offers a hands-on course in wildlife field techniques. The course includes exercises with birds, mammals, reptiles, amphibians, and vegetation. In one exercise the students set up trapping grids for small mammals; they set the traps and check, identify, weigh, and detail what is caught. The students practice working with the animals in labs, including learning the soundest procedures for administering anesthesia and injections; and they also practice handling and radio-tracking techniques (Mastron, 1995).

The LGCAs' emphasis on experiential learning must be appropriately balanced with liberal arts and general education requirements. As Allen (1992:p. 190) writes,

> … certain concepts and principles must be taught as part of an appropriate foundation for present and future learning that is a part of how we define an "educated person." Among these "musts" are … communication skills, problem solving, cross-cultural understanding, important disciplinary concepts, and sufficient grounding in liberal arts and interdisciplinary courses to serve as foundation for further personal or professional growth by the individual.

As the earlier discussion of student test scores and employer needs suggests, LGCAs must expect their students to meet minimum standards in these concepts and principles before they can be considered adequately prepared for graduate programs and the contemporary work place.

OPPORTUNITIES FOR DISTINCTION

Land grant colleges still have the major role in agricultural education, particularly at the graduate level, but they also have considerable competition. Many colleges and universities that are not part of the land grant system educate undergraduates in general agriculture and agricultural business and management, in particular. As noted in the *Profile* report, in 1992, non-land grant colleges and universities conferred approximately 20 percent of the undergraduate degrees in agriculture, food, and natural resources generally and about 30 percent of the undergraduate degrees in agribusiness (National Research Council, 1995a). Many of the non-land grant colleges and universities, including community and other 2-year colleges, have excellent programs and reputations in community service, as well.

Additionally, non-land grant universities—both public and private—are responding to student interests in natural resources and the environment, and some of the most innovative programs are at these institutions. The *Profile* report also notes that in 1992 non-land grant institutions conferred approximately 25 percent of the baccalaureate degrees in natural resources and approximately 33 percent of the master's degrees (National Research Council, 1995a).

In addition to its unique opportunity to enrich the academic experience through linkages among research, extension, and teaching, the committee believes the LGCA

"TRANSDISCIPLINARY" TEACHING AT THE UNIVERSITY OF MARYLAND

The Institute for Ecological Economics (IEE), established in 1991 by the Center for Environmental and Estuarine Studies of the University of Maryland system, became a joint venture with the College of Life Sciences and is also now associated with the School of Public Affairs at the College Park campus. IEE is the first American institute in an emerging global network of such research centers using the transdisciplinary approach to teaching. Ecological economics, a transdisciplinary program, draws from ecology and economics and the subdisciplines of environmental and resource economics so as not to be bound by them but rather to create an effective and essential synthesis of information.

The IEE curriculum provides theoretical and problem-oriented training. Contrary to interdisciplinary teaching, where students take a group of standard courses from different disciplines, new methods of teaching are employed in the IEE curriculum. The new teaching concept focuses on providing guidance to the students on how to tie together information from different disciplines. This scientific "atelier" (artisan's workshop) method of teaching combines an interdisciplinary workshop, case study, design studio, and guest lecture system that can be focused on a specific research topic.

The concept of ecological-economic simulation modeling of ecosystems is an important component of the graduate-level curriculum at IEE. The modeling is used to assess the potential values of ecosystem services, given ecosystem controls, management options, and feedbacks within and between the ecosystem and human sectors. Hardware and software tools are available that allow nontechnical computer users to create, implement, and test spatio-temporal ecosystem models on a wide range of platforms. The output of the models can be viewed by the user, providing practical information for valuing natural resources and setting public policies. There are options for altering the model dynamics to create certain scenarios. Statistical models and landscape pattern indices can be used in conjunction with ecosystem models to quantify risks to ecosystems.

Dynamic spatial models are also developed with the goal of providing a realistic description of past environmental situations and human behavior, while predicting the impacts of alternative policies on the environment and future human behavior. Dynamic modeling can be used, for example, to answer the question of how the services provided by a vegetative ecosystem at both a local and international scale are influenced by alien plant invasion and different management strategies. The benefits and costs of management scenarios can be addressed using information from a broad range of disciplines to estimate the value of harvested products, tourism, associated product yields, and biodiversity. In this instance, an interactive model will allow the user to set features such as level of harvest, extent of alien plant clearing, fire management strategy, and park visitation rates. The model output often proves to be a valuable tool in outlining the benefits of immediate investment to address current problems and the potential cost implications, if any, of delayed action.

system has opportunities for distinction in several important areas of its academic programs: environmental sciences and systems approaches, teaching science through food and agricultural systems, and creating a "marketplace for ideas."

Environmental Science and Systems Approaches: Programs Built on a "Sense of Place"

> Land grant universities were founded on a sense of place: an integrated landscape containing people who needed help. They were directed at altering the environment for the better, with better farmers and mechanics as tools. They realized that people were at once the primary problem and the principal resource (Gordon, 1992: p. 51).

LGCA's have been concerned with the interactions of farmers and the land and the elements, and they have focused on those interactions in specific locations. Education in agricultural specializations, particularly at land grant colleges, has been unique in part because of its connection to the site-specific research of the state experiment stations. Although certain principles are generalizable, crop yield depends on the adaptability of crop varieties to specific soil, water, and climatic conditions or on the development of new varieties better suited to local growing conditions. Thus, "sense of place" has a general meaning (linking people to their environment) and a specific meaning (serving the place-specific needs of people whose livelihoods depend on a productive agricultural enterprise).

Given their roots in a "sense of place," LGCAs are potentially well situated to lead the way in education that focuses on understanding the natural environment and how human cultures both affect it and adapt to its changes. Some colleges are moving in this direction by expanding their agricultural science curricula, in response to national needs and student interests, to include environmental sciences.

Some make the point that agricultural sciences are environmental sciences. In his remarks in 1968 regarding his vision for the college of agriculture at the University of California at Davis, James H. Meyer said,

> Its title, "College of Agricultural and Environmental Sciences," reflects the name change made in 1968 when we knew we had responsibilities for both agricultural and environmental sciences. My first recommendation is to change that title by deleting the "s" from Sciences. We should be the College of Agricultural and Environmental Science. The two adjectives must be said together to define the unique science for which we strive. Agricultural science alone or environmental science alone no longer exists nor was it ever possible.

The colleges' scientists and extension specialists are, more than ever, researching ways to facilitate the adoption of sustainable farming practices that are, for example, less chemical intensive and more in touch with both on- and off-farm environmental impacts. They are thus beginning to replace, for example, the vision of soil as a growth medium for corn with a regard for soil as an integral part of a delicate landscape, an ecosystem, a global marketplace, and necessary for sustainable human development. The colleges could also be building on the close proximity of their agricultural and forestry programs—at times in the same college, at times in separate administrative units (National Research Council, 1995a)—to develop a more integrated approach to landscape management that takes into account both crop and forest production systems and their interactions.

As they build their environmental science programs, land grant colleges could be at the forefront of the development and teaching of a "systems approach" to the conduct of science. A systems approach takes a broad rather than reductionist view of how things work, and thus describes how a set of elements or components are related and how those relationships are relevant to problematic situations (Checkland, 1981). Many believe a systems approach adds relevance to the reasons why things are learned and helps to define science in a broader perspective.

The resolution of many agricultural and environmental problems requires an approach that accounts for complex physical, biological, and behavioral relationships and thereby integrates contributions from multiple disciplines (Corson, 1995). For example, developing sustainable animal agricultural systems requires the integration of research in agronomy and soil science, ecology and ecosystems analyses, engineering, animal nutrition, population and community biology, and economics (National Research Council, 1994a).

Agricultural scientists have made significant progress in the modeling and simulation of agricultural processes over the last 25 years. For example, applied systems models are available to simulate processes such as weather, hydrology, nutrient cycling, tillage, soil erosion, soil temperature, crop growth and development, animal production functions and systems, and agricultural markets (Vietor and Moore, 1992). These models enable instruction to rise above the qualitative sphere—encompassing factors that influence the system—to the dynamic and quantitative domains, that is, how fast and how much.

RECOMMENDATION 8. *The federal government should expand competitive challenge grants to creative teachers and teaching teams to develop innovative multidisciplinary and systems-based course material and curricula.*

Agricultural scientists are well positioned to apply these systems concepts and approaches to a broader array of problems—including those relevant to urban environmental systems—and to introduce them effectively in the classroom to both agricultural and nonagricultural science majors. Nonetheless, Bradshaw and Marquart (1990), as observers of today's land grant education, argue that,

> In agriculture, there are many varieties of well-trained specialists: entomologists, plant pathologists, crop and soil scientists and others. Despite this high degree of specialization, or perhaps due to it, the delivery network for independent, multidisciplinary agricultural systems expertise is not in place. … Agricultural education and research respond to the needs of scientists and their disciplines, but less so to the needs of the production system and its practitioners—needs which extend beyond any single discipline.

Service to the University

In addition to the opportunities for leadership in applying and teaching multidisciplinary science and systems-based methodologies, LGCA faculty can use food and agricultural systems applications to teach science, providing core courses that enable students to meet university-wide requirements or requirements of science departments not located in the college of agriculture. Taking this approach not only helps students understand how basic science is relevant and useful to real problems, but also places agriculture more squarely within the scientific context (Handelsman, 1992) and opens LGCAs to a wider spectrum of students. For example, in the plant pathology department at the University of Wisconsin, a traditional course in micropathogens of plants was replaced with a course dealing with the basic principles of host-parasite interactions and critical analysis of scientific papers using examples from the plant pathology literature (Handelsman, 1992).

A Marketplace for Ideas

> Every citizen participates in the formulation of public policies that impact on agriculture. Thus, every citizen affects agriculture, just as every citizen is affected by agriculture through the quality and value of its products and by the effects agriculture has on natural resources and the environment. [from University of California course material]

TEACHING SCIENCE THROUGH AGRICULTURE

A salad, mashed potatoes, a rice and bean dish, or a package of brown sugar can link the science of botany to everyday reality for college students. Because plants have innumerable functions, from their use as foods to their application in clothing, shelter, and medicines, they are uniquely suited for use in teaching science and integrating it with historical, sociological, and economic issues. "Seeds of Change: The Uses of Plants" is a course developed at Pennsylvania State University as part of a new initiative in undergraduate education that uses a creative approach to training young scientists.

Traditional botany curricula stress biological principles but may not establish the connection between the chemical and biological features of plants and their importance in the health and welfare of animals and humans, the environment, and the economy. Investigating structural, nutritional, and chemical characteristics of plants can provide the basis for why different plants have specific uses, methods of cultivation, and are distributed in particular geographical areas. Dramatic changes in civilization brought about by plants, such as alterations in diet and increase in population catalyzed by the spread of western hemisphere crops to Europe—the Columbian Exchange—illustrate their worldwide social and economic significance. Through photosynthesis and oxygen production, plants are the major producers of biomass and consumers of the greenhouse gas carbon dioxide—a concept students relate to as a way of understanding global warming. Plants have evolved to an astounding diversity of forms, sizes, shapes, colors, and smells, and as a result of their many unique features they are essential to a wide array of animals and humans, from hunter-gatherers searching for food to scientists searching for a cure for cancer and AIDS.

Going beyond the conventional lecture format, "Seeds of Change" offers students an opportunity to explore plant science through in-class demonstrations and field assignments. Demonstrating the extraction of oils from various plant sources gives students first-hand experience with the methods used to manufacture perfume. Examining the components of a salad prompts students to discover that the "crunchiness" of lettuce is a result of its cellulose content and the orange color of carrots is a result of the vitamin, beta-carotene. Field trips to observe wild flowers in designated sanctuaries and to the National Arboretum in Washington, D.C., emphasize the role of plants in the origins of agriculture and medicine. Testing their knowledge, students are asked to develop questions for a game of trivia in which questions are organized into categories including history, economics, foods, and medicinals. The source for questions must be documented, which requires students to search the scientific literature and complete reading assignments. Students can also participate in a potluck dinner designed to reflect the widest possible diversity of plant uses for food.

The issues surrounding agriculture epitomize the complex and challenging choices that society and citizens must make. Colleges of agriculture can play an important role in teaching students how to engage constructively and collaboratively in resolving "real life" issues. The major components of collaborative problem solving are (a) developing a philosophy of co-learning in which everyone participates; (b) treating all ideas with

respect; (c) team facilitation; (d) goal and boundary setting; and (e) separating the creative process from the decision making process. Interactive learning, listening carefully to all viewpoints, and learning how to effectively influence the thinking and action of others are the key to collaborative problem solving. Classes that encourage creativity and stimulate synergism in a team approach to problem solving provide students a foundation for working successfully with their future professional peers and in their communities.

The colleges of agriculture should lead the way in producing graduates well prepared to engage in collaborative problem solving in the food and agricultural system. However, to take this leadership role, many colleges must continue to make progress in overcoming the perception that they serve a narrow segment of society.

Agriculture represents the confluence of many different interests, groups, and sectors of society. Consequently, the colleges of agriculture potentially have a considerably larger role in providing training and course work in the social and behavioral sciences than many now play. Some colleges of agriculture have taken on this role. As an example, the College of Agricultural and Environmental Sciences at the University of California at Davis administers an interdepartmental undergraduate teaching program in science and society. Students are offered courses that integrate the physical, biological, and social sciences and simultaneously introduce the basic subject matter of the college. General education courses highlight the food and fiber systems and their connections to environmental resources and the health, safety, and well-being of workers and consumers. Upper-division courses emphasize integrative and synthetic intellectual skills, coupled with an emphasis on creative problem solving and service to society. Courses often involve more than one professor and draw on team or panel teaching approaches. A class in agricultural biotechnology, for instance, looks at the potential societal impact of various technologies, factors shaping public opinion, and ethical and moral questions being raised about the application of new biotechnologies (University of California, Davis, 1993).

SUMMARY AND RECOMMENDATIONS

Land grant precepts for access and education for the citizenry remain in the national interest despite the fact that most U.S. citizens have attained a relatively high level of education. There are, nonetheless, some growing challenges to these historical goals, including increases in tuition and declines in student aid—developments that fall most heavily on poor and lower-middle class families. The colleges of agriculture have unique opportunities to contribute as leaders to the ongoing realization of the land grant vision, but they also face extra challenges that they must overcome.

Agricultural and food systems education remains vitally important to the nation and the world (and the agricultural interests of the nation and world are interdependent), particularly as world population expands, natural resource constraints tighten, and human health care costs stress economies. Indeed, the demands of agricultural education have expanded as the business of agriculture has become increasingly industrialized and global; as knowledge of plant and animal genetics and ability to control genetic characteristics has grown; and as the complex interactions between agricultural production and the environment and between genotypes or production methods and food attributes and human health have become better recognized and of increasing concern to society.

Inasmuch as agriculture is an advanced science- and technology-based industry that has everyday relevance to peoples' lives, food and agricultural systems courses are a vehicle for teaching life, physical, and social sciences to both science and nonscience majors and for underscoring the practical applications of science to modern life. The linkages between the college of agriculture and the university can and should be enhanced through this strong connection between agriculture and science.

Agricultural and food systems education should maintain the disciplinary strength it developed as the agricultural disciplines matured, while also offering its graduates

interdisciplinary perspectives, the ability to work in multidisciplinary teams, and the tools to analyze systems comprised of interacting biological, physical, and economic processes. Such tools and perspectives are needed by both modern-day farmers, who must be sophisticated managers of biological and natural resource systems, and by public and private entities attempting to understand and manage interactions among production agriculture, natural resources and the environment, human health and the well-being of human communities.

Because of their historical role in developing a science base for understanding human interactions with our natural environment, the land grant colleges are natural leaders in developing and teaching modern environmental sciences. Environmental sciences are of great interest to students and society today. The land grants can take the lead in viewing agricultural resources as part of a larger ecology; they can thereby expand the relevance of their programs to a wider set of students and societal issues; and they can take a more constructive role in bridging and integrating the interests of farm and nonfarm clientele by providing students with the tools for undertaking systematic and quantitative analyses of opportunities and challenges in the food and agricultural system.

In sum, the committee believes there is significant potential for enhancing the quality, breadth, accessibility, and relevance of LGCA teaching programs. Given the relatively modest federal funding available to stimulate innovations in food and agricultural system teaching programs, the federal role is limited to providing incentives for state and institutional initiatives. To successfully stimulate innovations, the committee recommends the federal government target its resources to initiatives such as

- supporting the bridging programs and articulation agreements among institutions (Recommendation 6);
- supporting mentored internship opportunities that reflect the diversity of contemporary career settings for graduates in the food and agricultural sciences (Recommendation 7); and
- stimulating and rewarding the development of innovative multidisciplinary and systems-based courses and curricula for food and agricultural systems education (Recommendation 8).

The committee also believes that internally generated and state supported changes in LGCA teaching programs are needed to better prepare students for the challenges of a dynamic, complex, and consumer-driven 21st-century food and agricultural system and to strengthen the future of the LGCAs. Examples of needed structural changes that are discussed and recommended in this chapter, and in Chapter 2, and that require significant institutional leadership, are the following:

- Integrate teaching and learning opportunities more fully with research and extension through, for example, involving undergraduates in research, and enhancing the role and status of extension in academic programs.
- Reduce barriers to multidisciplinary and interdepartmental approaches to teaching and learning through, for example, rewards for and recognition of team scholarship.
- Develop long-term, comprehensive regional consortia to reduce duplication, differentiate course offerings, create inter-institutional faculty teams, capitalize on distance learning technologies, and broaden experiential learning opportunities.
- Strengthen relationships with and build bridges to other units of the university by, for example, developing courses that fill general education requirements in the sciences and humanities and that place food and agricultural issues squarely in the scientific context.

4

Research

The overarching recommendations in Chapter 2 were developed to enhance the accessibility and relevance, organizational efficiency, institutional strengths, and accountability of LGCA research and education. The recommendations stress broad stakeholder input, regional and multi-institutional approaches, and synergies among teaching, research, and extension. They also put emphasis on outcomes and critical evaluation. In this chapter, the discussion focuses on the research function—specifically on four institutional features of the LGCA research system:

1. federal research monies and the share of competitively awarded funds in the total federal support of food and agricultural research;
2. the institutional status of the 1890s in research;
3. public-private partnering in research; and
4. inter- and multidisciplinary research funding.

Alternative models for allocating competitive grant funds for food and agricultural research are also reviewed.

THE NATIONAL INTEREST

The national interest in maintaining a high-quality, productive research base in food and agricultural sciences is compelling and multifaceted. U.S. consumers are demanding more from the domestic food and agricultural system than the system is accustomed to providing. Aside from wholesome, abundant, and reasonably priced food, consumers expect environmental enhancement, increased food safety and nutritive value, and opportunities for small-scale farmers (Reichelderfer, 1991). These are public goods toward which, historically, only minor proportions of the agricultural research effort have been devoted.

In the 1960s the Green Revolution initiated the use of food crop hybrid varieties and improved management systems, dramatically increasing food grain production. Since then, however, much has been learned about the potential some of the modern production practices have to degrade the natural resources on which food production ultimately relies. Rates of gain in average rice yield have recently slowed throughout Asia; and

yields have actually declined in some countries, despite the continuous introduction of improved rice varieties—a phenomenon thought to be related to the decreasing productivity of intensively cultivated soils (Pingali, 1994). These developments are important because over the next 30 years world population is expected to grow by nearly 100 million people per year, with most growth occurring in developing regions (Prinstrup-Anderson and Pandya-Lorch, 1994).

The United States has provincial as well as altruistic reasons for its interest in preventing world population growth from translating into global poverty, widespread malnutrition, and environmental degradation. Global political, social, and economic stability are necessary for the realization of expanded markets for U.S. industrial as well as agricultural goods. Market expansion relies absolutely on the availability and implementation of technologies and policies that increase agricultural production, while simultaneously enhancing and sustaining social and natural systems. A sound research base is needed as the foundation for development and application of those technologies and policies.

Historically, high social rates of return,[1] estimated to be between 30 and 50 percent, have resulted from investment in agricultural research (Alston and Pardey, 1995b). These estimates compare favorably with returns on conventional investments in the private sector (Fuglie et al., 1996), which suggests a system is in place capable of maintaining a high-quality, productive research base in food and agricultural sciences. Yet, challenges and potential opportunities lie ahead as that system adapts to a changing ecology of science, characterized by constraints on federal funding, increased public awareness of social problems that research has been unable to resolve, and consequential public dissatisfaction with science and government (Byerly and Pielke, 1995).

Ensuring a Sustainable High- Quality, Productive System

Ensuring a socially, economically, and ecologically sustainable food and agricultural system requires scientific advancements across the entire scope of a discovery-integration-dissemination-application continuum, identified by Boyer (1990). This committee uses "research continuum"—denoting interactions among fundamental, integrative, adaptive, and disseminated research—to refer to what is described by Boyer (1990) and Malone (1994) as the "cascade of knowledge."

Fundamental research on the structure and functions of systems as small as genes, as critical as cells, as complex as organisms, and as large as agroecosystems is the essential basis of the discoveries needed to advance food and agricultural performance.

Integrative research is needed to combine fundamental discoveries and thus gain the comprehensive knowledge required to develop more targeted practices, technologies, or policies. Independent, fundamental research programs have been useful in the discovery of (a) the gene that confers resistance in a particular food crop species to a particular plant disease of viral origin; (b) similar chemical compositions of plant leaves in a variety of wild and cultivated plant species that exhibit natural resistance to viral plant pathogens; (c) disease-resistance characteristics of crop species bred for high yields; and (d) the relative, economic values of different attributes of crop species' varieties. These separate discoveries by scientists in different disciplines (genetics, plant physiology, crop breeding, and economics) have their greatest potential value realized when related to one

[1] The social rate of return on an investment in agricultural research or technology development includes the economic returns to the technology developer, farmers and other producers, and consumers. Beneficiaries of public agricultural research investments include those who use the research results in their production processes, such as farmers, input manufacturers, food and fiber processors, and consumers, who benefit through lower prices for food and agricultural products. A number of important social benefits, such as human health, environmental quality, improvements in family life and community development, and public decision making are typically omitted from the social rate of return on a research investment because of significant measurement difficulties.

THE CASCADE OF KNOWLEDGE

Sustainable human development is the basic goal of advancing knowledge and education. The "cascade of knowledge" is the essential operating principle for assuring that research and education work toward that goal.

An overarching challenge for the twenty-first century will be to manage human affairs on planet Earth in a manner that will enable … sustainable human development. Sustainable human development is characterized by economic growth that emphasizes the quality rather than the quantity of that growth. It distributes equitably the benefits of that growth. It … regenerates rather than degrades the life-supporting capacity of the environment.

Human progress on planet Earth is presently on a path of exponential and asymmetric demographic and economic growth that is unsustainable, inequitable, and unstable. Critical factors in reconciling needed and equitable economic growth with maintenance of global environmental quality are: rates of population growth and gains in economic productivity; the distribution of these rates among … countries; the efficiency of the technological infrastructure that converts natural resources into goods and services; and the behavior of individuals and institutions in the socioeconomic system who consume those products and utilize those services.

Each of these factors is powerfully influenced by the cascade of knowledge. This cascade consists of the discovery, integration, dissemination, and application of knowledge concerning the nature and interaction of matter, energy, living organisms, information, and personal behavior. A global knowledge strategy is needed to develop this cascade worldwide. The strategy will require unprecedented collaboration among the physical, biological, and social sciences, engineering, and the humanities. New modes of communication and cooperation will be required among: academia; business and industry; … government; private organizations; and individuals at the grass-roots.

The mission of institutions of higher education involves knowledge in all of its aspects. They, therefore, have a special opportunity and responsibility to exercise leadership in the development of a global knowledge strategy (based on the cascade of knowledge and dedicated toward human sustainable development).

SOURCE: Malone, T. F. 1994. Sustainable Human Development: A Paradigm for the 21st Century. Paper developed for the National Association of State Universities and Land Grant Colleges. Research Triangle Park, N.C.: Sigma Xi Center.

another in exploring alternative avenues for making crops more disease resistant without sacrificing other valued characteristics.

Adaptive research is needed to apply the findings of integrative research to actual production, processing, marketing, consumption, or environmental systems. This will result in development and testing of specific, practical solutions to existing food, agricultural, or natural resource problems. For instance, it is known that adding the intestinal enzyme, phytase, to poultry or hog feed can decrease the amount of phosphorus in animal excretions and thus reduce the environmental threat posed by animal waste.

Research is still needed, however, to identify such things as the best delivery system for phytase and the implications of its use in determining optimal agronomic (or maximum legal) rates of manure spreading on crop fields. Adaptive research is essential to determining the institutional arrangements affecting distribution of costs and benefits of phytase use among contract hog or poultry producers, firms that integrate production, processing and marketing of pork and poultry products, and consumers of both meat products and environmental goods.

Dissemination of the fundamental, integrative, and adaptive research assures that the innovations and applications discovered thereby are transferred to those individuals, groups, firms, or government bodies that can use them to accomplish personal and collective benefits.

The research continuum is not strictly linear. Feedback can and must occur, for example, when adaptive research indicates there is a critical gap in fundamental knowledge or when an integrative research result directly alters the value of disseminated research (Figure 4-1). The feedback loops on which the research continuum or "cascade of knowledge" rely directly depend on the integration of research and extension throughout a large area of the continuum (see Recommendation 4). For that reason, the committee consciously avoids contrasting the value of or need for basic or fundamental research with that of applied research; the argument itself is without value. The benefits of fundamental research to society cannot be realized without follow up through integrative and adaptive research. In turn, applied research relies on new discoveries and, itself, discovers new needs for fundamental investigation.

The Federal Role

As discussed in Chapter 2, federal support is needed for and should be targeted to research that results in the provision of public goods that cross or transcend political boundaries. Basic or fundamental research meets the public-goods criteria because it creates new knowledge that is generic, nonappropriable, and openly available, and it may be done with no specific application in mind (National Academy of Sciences, 1995). Integrative, adaptive, and disseminated research directed at the provision or enhancement of public goods, such as environmental quality, public health and safety, equity and economic opportunity, and informed public decision making, also meet the public-goods criteria. Federal support may be justified also when the commercial markets for the research products are too small for adequate private gain or when the private sector's incentive to invest in research is otherwise low in relation to the anticipated benefits to producers and consumers. There are multiple public funding sources for basic biological science research (for example, National Science Foundation [NSF] and National Institutes of Health [NIH]) and the private sector is most likely to pursue or support adaptive research with commercial potential; therefore, the committee believes there is a special need for further federal support of integrative research in the continuum of food and agricultural systems research.

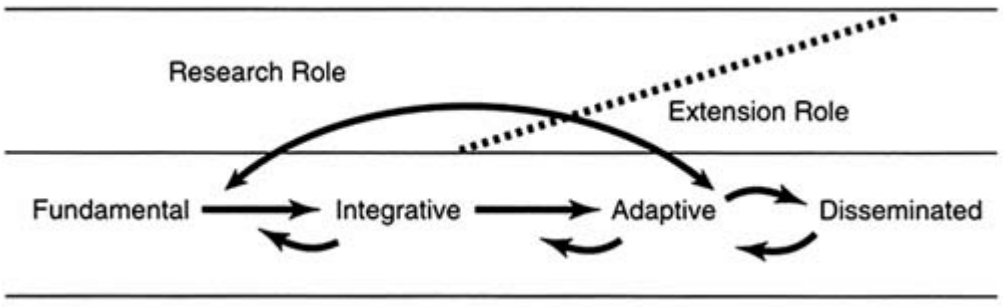

FIGURE 4-1 *The research continuum.*

Data are not available to determine the percentage of agricultural research expenditures allocated to fundamental, integrative, adaptive, or disseminated research categories. The CRIS system, however, does stipulate that research investigators should report how much of each research project is basic research and how much is applied research. The data show that applied research accounts for more than one-half of the LGCA research conducted with formula funds, congressionally designated special research grants, state appropriations, and industry grants. On the other hand, LGCA research conducted with USDA-administered competitive grants and other federal agency grants is much more heavily weighted toward basic research (Ballenger and Kouadio, 1995).

STRUCTURE AND PERFORMANCE OF THE CURRENT LAND GRANT RESEARCH SYSTEM

The fundamental structure for the research system based in the land grant colleges of agriculture was established in 1887 by the Hatch Act. It is stated in that act that general, federal research support would be routinely provided to state agricultural experiment stations and administered through USDA. Such is still the case, and legislated formulas established in 1955 for federal research fund allocation also remain in effect today (National Research Council, 1995a). There have been, however, significant changes: the addition of "special grants" program funds in 1965 (Public Law 89-106) and the initiation of a Competitive Research Grants program in 1977 (Title XIV of the National Agricultural Research, Extension, and Teaching Policy Act)—awards not limited to the experiment stations. The Food, Agriculture, Conservation, and Trade Act of 1990 (the 1990 farm bill) expanded the competitive grants program by creating the NRI.

What is important now is whether this long-lived structure and the institutional arrangements influencing the nature, quality, and direction of LGCA research are still adequate and appropriate. Can this structure meet the research challenges of the future, federal budget problems, and growing demands for accountability?

Federal Research Funds and Allocation Mechanisms

Federal research and development (R&D) funds totaled $69 billion in 1994. Less than $1.5 billion (approximately 2 percent of total federal R&D or $6 per person) was used for R&D conducted or administered by USDA (Table 4-1). Evidence from the economics literature of the high social rate of return flowing from investments in agricultural research, coupled with the sizeable national interest in the performance and sustainability of the U.S. food and agricultural system, suggest the nation's investment in agricultural research is indeed a modest one.

Of total USDA-administered support for agricultural research in 1994, roughly 70 percent supported intramural research and information activities of USDA agencies, 15 percent was allocated by formula to the LGCAs and their experiment stations, and less than 7 percent was awarded competitively to institutions including but not restricted to experiment stations (Table 4-1). Compared with research administered by other federal agencies, USDA-administered R&D funding is distinguished in three ways. First, it is the only federal research funding of which a portion is distributed to a fixed number of institutional recipients by a formula. Second, compared with federal support of research designated for generating knowledge in basic science, medicine, energy, and the environment, the proportion of competitively awarded agricultural funding is exceptionally small. Only the Department of Defense has a smaller proportion of "merit reviewed" and competitively awarded research funding. Finally, of the agencies shown in Table 4-1, USDA has, by far, the largest intramural proportion of federal R&D expenditures.

The fact that 15 percent of competitively awarded federal funds are allocated by formula to the experiment stations is part of the reason for the small proportion of those total funds for agricultural research. The historical and continuing rationale for formula funding is that it assures the pursuit of food and agricultural research, which often has site-specific requirements, across all states whose economies rely on agricultural production and rural vitality and contribute to the nation's food supply. The distribution of this

TABLE 4-1 Federal Agency Research and Development Support, 1994

Agency	Total for R&D and R&D Facilities ($million)[a]	Allocated for Intramural Research (percent)[b,c]	Allocated via Merit Review and Competition (percent)[d]
U.S. Department of Defense[e]	35,800	26	5.2
U.S. Department of Health and Human Services[f]	10,697	21	79.0
U.S. Department of Energy	6,880	21	46.0
National Science Foundation	1,984	2	98.0
U.S. Department of Agriculture	1,484	70	6.6
U.S. Environmental Protection Agency	440	25	19.0
Total	68,923	28	36.0

[a] Actual outlays for 1994, as reported in tables developed by the Office of Management and Budget (OMB), Budget Analysis and Systems Division (January 30, 1995).
[b] Calculated from data in Table C-9, Federal Funds for Research and Development, Vol. 42, Fiscal years 1992, 1993, 1994, National Science Foundation, NSF 94-328.
[c] It should be noted that some intramural research funds do get allocated to academic and other research institutions via agency contracts and cooperative research agreements.
[d] Calculated from OMB data, Budget Analysis and Systems Division (January 30, 1995), reporting "merit reviewed scientific research with peer evaluation and competitive selection." Includes intramural research meeting this criteria, as well as (mostly) extramural research.
[e] Military agencies.
[f] The National Institutes of Health (NIH) alone represents 94 percent of HHS obligations for R&D; and intramural research represents 19 percent of NIH R&D. NIH's own data show the total for R&D and R&D facilities to be $10,328,117 ($million), of which 11 percent is intramural research (i.e., NIH data show a smaller percentage of intramural funding [National Institutes of Health, 1994]).

funding is based on a formula related to farm and rural populations (National Research Council, 1995a). Formula funding contributes to the diffusion throughout the nation of food and agricultural system research and also has other advantages.

- The stability and flexibility of research supported by formula funding facilitates pursuit of long-term research goals and multidisciplinary and extradisciplinary research. Some argue that such research is unlikely to be requested through current competitive granting vehicles, which provide shorter-term funding specific to topical areas that shift over time according, in part, to the scientific and political popularity of researchable issues. A special class of long-term research particularly important in agriculture is "maintenance research," which is required to reinvigorate past research gains that over time have deteriorated. For example, new plant varieties may perform well for several years but then yield less as predatory insects or diseases evolve (Blakeslee, 1987). One study indicates that maintenance research accounts for as much as one-third of all production-oriented agricultural research in the United States (Adusei and Norton, 1990).
- Formula funding has permitted the evolution, peculiar to LGCAs, of a system in which the time and effort of many faculty appointments are split among some combination of research, extension, and teaching. Those faculty whose research appointments are wholly or partially funded by federal formula funds and/or their state matching funds, who also have extension or teaching appointments or both, automatically manifest an inherent linkage of research with ongoing extension and teaching activities. This close, structural linkage of individual researchers, and the experiment stations where they work, to extension and teaching responsibilities is a unique and valued feature of the LGCA-based agricultural research system. When it works (and the pressures on those linkages were discussed in Chapter 2), it facilitates development of a cascade of knowledge.

- The availability of stable research funding through formula allocation reduces the proportion of researchers' time spent applying for competitive grants. Because grant application processes are time consuming and can have low rates of success, formula funding means that relatively more of a researcher's time can be devoted to actually performing the funded research (Huffman and Evenson, 1993).

On the other hand, noncompetitive funding, by formula or congressionally designated special grants, is inherently inequitable, inefficient, and lacking in accountability.

- The exclusion of research institutions other than the experiment stations from more than $200 million in federal agricultural research funds is unfair. Equally important, it precludes a completely efficient process for matching those researchers uniquely qualified to address specific food and agricultural problems with the funding to address those problems (Alston and Pardey, 1995).
- Formula funds and special grants have carried with them no effective means for accountability in terms of how they have been used by state institutions or whether they have been devoted to research issues that justify federal support. There is no generally accessible public record, including the CRIS system, that documents and provides a rationale for the specific uses of formula funds by the experiment stations.
- Research conducted with formula and special grant funds is not automatically subject to peer review. Despite a large number of valid criticisms of the way peer review tends to operate, even its most vocal critics see peer review, at least as reformed to operate more equitably and efficiently, as the key to quality control in scientific endeavor (Chubin and Hackett, 1990).

The lack of competitive funds designated for agricultural research multiplies the incentive for experiment station and other food and agricultural scientists to seek such funds competitively from other sources. In 1992 experiment station research at 1862 LGCAs was supplemented by $226 million in funds from NIH, NSF, the Department of Energy, the Environmental Protection Agency, and other federal funding sources (National Research Council, 1995a). A majority of these supplemental funds are presumed to be competitive as most are attributable to NIH and NSF, whose research allocation processes are almost exclusively project-based and competitive. There is some consternation within the agricultural community that, by virtue of the greater availability of these funds relative to funding designated for food and agricultural research, some of the best and brightest of the experiment station researchers have avoided food and agriculture system issues and research needs.

The committee concludes that there is a need to preserve the advantages offered by formula funding, particularly their facilitation of linked research, extension, and teaching programs (which is the basis for Recommendation 4). However, the relative lack of competitively awarded and peer-reviewed research specific to food and agricultural system issues places severe limitations on the ability of the land grant system and other research institutions to meet the research challenges of the future.

A large role for competitive funding in agricultural research would lessen the perception that agricultural research is separate and insulated from the rest of the scientific community.

RECOMMENDATION 9. *The federal government should increase competitive funding of food and agricultural research projects. The funding level for competitive grants should be no less than the $500 million authorized by Congress for the National Initiative for Research in Agriculture, Food, and the Environment (NRI). Additionally, the share of total federal research support awarded competitively to projects and individuals (including teams) on the basis of peer-reviewed merit should be increased. Recognizing fiscal constraints, options for increasing the share include (a) directing funds to research from other USDA budget categories, particularly as a means of reinvesting savings on agricultural subsidies; (b) transferring to competitive grants programs*

A PROFILE OF TWO STATE AGRICULTURAL EXPERIMENT STATION RESEARCHERS

Professor F: A Plant Scientist Supported Primarily by Formula Funds

Professor F works in the Plant Science Department in a College of Agriculture in the Great Plains. His primary responsibility is to develop new varieties of wheat with desirable agronomic characteristics including high yield, desirable baking characteristics when ground to flour, and resistance to drought, mildew, and insects. This scientist's specialty is insect resistance, and he currently concentrates on resistance to the Russian wheat aphid, although other agronomic characteristics must continually be monitored. At any given time, thousands of strains of wheat and their crosses are being studied. Typically, from identifying a desired new trait in wheat (such as aphid resistance) to releasing a new variety to farmers or seed companies takes 12–15 years. Note that many varieties in various stages of development for several purposes are continually being researched, but a new variety is released from this laboratory only every 3 to 4 years, and a truly exceptional variety that is widely adopted about once each decade. When that occurs, however, the economic impact averages millions of dollars/year for many years.

This scientist collaborates with similar plant breeders at seven other state experiment stations; they test each other's varieties in a spectrum of climates and the serendipitous differences that occur from year to year and site to site such as rainfall, temperature, and insect damage. In addition to field experiments, Professor F does considerable laboratory work, particularly in defining the nature of aphid damage to plants. This is done in a secure greenhouse to contain the aphids. Current lab work concentrates on correlating concentrations and timing of appearance of a minor chemical component in wheat stems resistant to aphids. If measurement of this chemical can be substituted for measuring aphid damage, much more rapid progress in plant breeding will be possible because the chemical is easier and less expensive to measure than the more subjective current measures of aphid damage.

Professor F has an 80 percent research, 20 percent extension appointment. He deals with questions and problems concerning probable insect damage to wheat and other grain crops. In addition to providing advice on an ad hoc basis, he organizes two field days each year and has a circuit of meetings with wheat farmers that takes 10 days each winter. Although Professor F teaches no formal courses, he usually has two graduate students (one masters and one doctorate level) working under him at any given time; and their theses are written under his direction and with his resources. He also has services of a three-quarter time technician and hires two undergraduates on an hourly basis in the summer. About 90 percent of his annual funding of $190,000 is from formula funds; the remaining 10 percent comes from the State Wheat Board. These funds have been stable over the years, but technically are specified by the director of the state experiment station.

Professor C: A Plant Scientist Supported Primarily by Competitive Grants

Professor C works in a Plant Science Department in a college of agriculture in the "Corn Belt." Her primary responsibility concerns the biology of how the

cells of a newly developing plant get to be shoots or roots. It appears that the first cells produced after germination can be induced to develop in either direction, and of course for the plant to survive, both are needed. In some kinds of plants, when moisture is limited, more of the cells become roots, but with abundant moisture, the balance switches toward shoots. In other plants, it appears that temperature regulates this ratio instead of moisture, with higher temperature inducing more roots.

Professor C is trying to understand how these plants take moisture or temperature information and use it to regulate differentiation into roots or shoots. She uses molecular approaches, studying plant genes that are activated by compounds that the plant makes itself. Interestingly, one of these compounds seems to affect shoot growth negatively and root growth positively; at low concentration, shoots grow and at high concentration, roots grow preferentially. However, it is not clear how this chemical is made, how its production is regulated, or how it manifests its effects. Note that Professor C isn't really trying to solve any practical problem, although she believes that the information she is generating may be extremely valuable in future plant breeding applications. One example used to justify her work on grant applications is to induce extra root growth in situations where plants germinate in cold, wet conditions but likely will encounter hot, dry ones later in the season.

Professor C has a 50 percent teaching, 50 percent research appointment. She teaches one course each semester, a course on molecular biology of plant growth to graduate students in the fall and a junior-level botany course in the spring. She also advises eleven undergraduate students, primarily on curricular matters; she has a half-time technician and one Ph.D. graduate student, plus a post-doctoral student. Her salary funding is 50 percent resident instruction (teaching) funds from the University and currently 40 percent from a competitive grant funded by the National Science Foundation. She also usually applies each year for funding from USDA through the NRI (National Research Initiative) Competitive Grants Program. She has managed to have either an NSF or USDA grant funded at any given time over the past decade, in the $65,000–70,000 per annum range; she even had a 6-month period that included funding from both. She is concerned that there could be a spell when there will be no funding from either source, since only 10–15 percent of proposals typically are funded. In such a case, Professor C would be assigned additional teaching duties; she likely could get $10,000–15,000 from the experiment station director for 1 or 2 years with the hope that one of her competitive grant applications would be funded the following year.

a portion of the funds currently distributed to experiment stations by formula and special grants; and (c) drawing on USDA intramural noncompetitive research funding. Consistent with Recommendation 1, a two-tier review system similar to that of NIH should be used at the federal level to guarantee that public benefits as well as scientific merit guide the selection of research proposals.

In recognizing that new monies for competitively funded research implies funding trade-offs in an era of fiscal constraints, the committee refers to the conclusions and

COMPETITIVE GRANTS

The terms *competitive grants* and *peer review* mean different things to different people under different circumstances. The broad philosophy of these funding concepts is to fund research (or other projects) according to merit rather than some other criterion—for example, dividing resources equally among qualified applicants or constituencies. The challenge is to define and evaluate merit. Ideally, the organization providing the resources defines merit, and qualified reviewers who have been screened to minimize or eliminate vested interest (usually termed "peers," though they may not be peers technically), evaluate proposals. With this system, the best-qualified and most capable people and organizations usually obtain funding for research, so, in theory, the return on investment is optimized.

A problem, however, is defining what research is to be done. At the "basic" end of the research spectrum, the more limiting the criteria, the higher the probability of excluding a good idea that no one thought of previously but that might revolutionize a field. Therefore, to cast as wide a net as possible for good ideas, delimiters are minimized. For example, one might ask for proposals concerning biology of plants of agricultural importance. At the "applied" end of the spectrum, there might be a solicitation for research on methods of decreasing nitrate levels in the Chesapeake Bay; to be more specific, one could stipulate "nitrates originating from hog manure." Very specific criteria often limit eligibility, and this may or may not be appropriate. Most nongovernment agencies, foundations, and businesses use competitive grants mechanisms, although they may have other names like "requests for proposals." If absolute criteria are set, the process equates with competitive bidding on contracts.

The National Institutes of Health (NIH) uses a two-tier review system to guarantee both the scientific merit and public benefits of competitively selected research proposals. The first-tier review is by a group of scientific peers. The second-tier review is by a council of scientists and nonscientists that may take program and public priorities into account in making adjustments in funding decisions. In practice, the NIH councils have their impact largely at the margin of funding decisions, although they have the authority for more significant intervention (National Institutes of Health, 1992).

recommendations of two recent reports from the National Research Council and the National Academy of Sciences.

In *Investing in the National Research Initiative* (National Research Council, 1994a), the National Research Council's Board on Agriculture reaffirms its earlier (National Research Council, 1989) support for a much expanded competitive grants program for agricultural research. This committee concurs with the board's belief that competitive grants are the mechanism best suited to stimulate new fundamental research activities in specific areas of science and that they have unique advantages for food and agricultural systems research in relation to formula funds, special grants, and intramural research[2]: they are responsive and flexible, they attract a broad range of scientists from public and private institutions, and they cast a wide net—that is, they capture proposals that produce new alliances, new initiatives, and new approaches.

[2] In theory there are unique and distinct roles for the intramural research agency, the Agricultural Research Service (ARS), and the state agricultural experiment stations. In practice, however, these roles become blurred. One way to increase efficiency in the public food and agricultural research system is to ensure that the respective roles of ARS and the experiment stations (or colleges) are carefully delineated and synergistic, to avoid replication. For example, maintenance research and emergency response to crop pest infestations and livestock disease are important shared activities.

Allocating Federal Funds for Science and Technology, a National Academy of Sciences (NAS) (1995) report, addresses mechanisms for allocating federal research funds. The authoring committee recommends that federal science and technology funding should give preference to projects and people, rather than institutions, and that the awarding of grants should be based on competitive merit review. That report concludes (p. 25) that in relation to merit review of academic research,

> … merit review of in-house (that is, intramural) research is much more difficult because federal research scientists and engineers are in the civil service and still retain salary and benefits even if they are not productive or their area has lower priority or has become obsolete. That problem is a perennial one in the periodic reviews of federal laboratories.

Although the NAS committee recognized the important role for federal laboratories in a balanced program of federal science and technology, this conclusion underpinned its recommendation that federal funding should generally favor academic institutions because of their flexibility and inherent quality control.

Encouraging Participation and the Potential for Success

The committee also recognizes that as funds are redirected over time toward competitive grants programs, some experiment stations and colleges of agriculture will be at a disadvantage. As indicated in the *Profile* report (National Research Council, 1995a), the experiment stations that garner the largest shares of their research expenditures from competitive grants programs (administered by USDA, NIH, NSF, etc.) tend to be those associated with large research universities. Many LGCAs and experiment stations do not fit this description. The committee believes that competitive grants programs for food and agricultural research must be structured and administered so as to encourage participation by and potential for success to all institutions, particularly small and mid-sized institutions and those not among the top 100 universities and colleges receiving federal funds for science and engineering. One way to do this is to continue and further strengthen the role of USDA in the federal government's Experimental Program for Stimulating Competitive Research (EPSCoR).[3]

RECOMMENDATION 10. *USDA should continue its role in enhancing participation and success in competitive grant programs by all institutions in order to build human capital nationwide in food and agricultural research. For example, it should (a) continue to designate 10 percent of the enlarged competitive grants pool for institutions in USDA-EPSCoR states; (b) allocate 5 percent of competitive grants for 1890 institutions, while maintaining capacity building grants; and (c) streamline the federal competitive grants application process without sacrificing accountability or the adequacy of information on which to judge scientific merit.*

[3] EPSCoR is a National Science Foundation program designed to bring participant states' science and engineering research endeavors at academic institutions to nationally competitive levels. In each qualifying state, NSF's role is to stimulate local investment in the research infrastructure as well as to provide federal investment funds. USDA-EPSCoR states are currently those that have had a funding level from the USDA NRICGP no higher than the 38th percentile of all states, based on a 3-year rolling average, and all U.S. territories and possessions, including the District of Columbia. For FY 1996, the following states fall into this category: Alaska, Arkansas, Connecticut, Delaware, Hawaii, Idaho, Maine, Mississippi, Montana, Nevada, New Hampshire, New Mexico, North Dakota, Rhode Island, South Carolina, South Dakota, Vermont, West Virginia, and Wyoming.

Revising the Formula

The committee believes the current formula for allocation of formula funds for contemporary food and agricultural systems research does not reflect the broadened constituency, which is predominately urban and suburban. Current and future research is neither just—nor even primarily—for the benefit of farmers and rural residents. Although this fact is reflected in changes in the names of many land grant colleges of agriculture, it is not reflected in how their formula funding is calculated.

RECOMMENDATION 11. *A new formula by which food and agricultural research funds are allocated within the land grant system should be designed and implemented to accurately reflect the full range of food and agricultural research beneficiaries.*

Although reluctant to propose a precise equation for reallocations by formula, the committee recommends the consideration of variables such as states' proportionate contributions to total U.S. population, relative poverty rates, or shares of cash receipts from farm and food marketing as appropriate reflections of the LGCA system's broadened contemporary customer base. These variables could be used in many different ways as the basis for a revised allocation formula instead of, or in addition to, percentages of rural and farm populations. The committee stresses that the new formula should be applied to total allocations among states, not limited to annual, incremental increases (as changes are presently accommodated). It would expect, however, that such changes be phased in over an adequate adjustment period, rather than implemented immediately.

Any modification of the formula will result in some state agricultural experiment stations losing and others gaining some formula funding. The committee therefore suggests that a range of alternative formulas, and their implications, be studied to identify the ideal way to revise outdated formulas.

The Status of the 1890 Institutions

Federal legislation requires that state governments match the federal formula-based contribution to research conducted at the experiment stations located at 1862 institutions; in fact, states contribute far more than their matching requirements. However, no such requirement applies to federal contributions to research based at the 1890 institutions. Consequently, according to USDA's CRIS system, only 2 percent of the food and agricultural research funds at 1890 institutions come from state budgets. This means that every federal dollar for food and agricultural research at an 1862 institution goes at least twice as far as does a dollar of federal support to 1890 institutions.

Aside from the obvious inequity among institutions within the land grant system, this discrepancy in federal funding requirements also means that the clientele of the 1890 institutions are less likely, than is the clientele of the 1862 universities, to receive adequate research attention. The 1890s have been uniquely focused on issues, problems, and needs of African-American and other ethnic minority groups, small-scale and limited-resource farmers, and low-income rural and urban families (Godfrey and Franklin, 1992; Mayes, 1992; Rasmussen, 1989). The CRIS data indicate, as documented in the *Profile* report (National Research Council, 1995a), that 1890s devote significantly larger shares of their research resources to social sciences issues pertaining to people, communities, and institutions than do 1862s, in addition to those resources that they devote to food and nutrition issues. Forty percent of all farm-operator households are located in southern states (where the 1890 colleges are located); 60 percent of all farm-operator households classified as limited-opportunity households are also located in southern states (see Chapter 2 for a definition of "limited-opportunity farm-operator household") (U.S. Department of Agriculture, Economic Research Service, 1996).

The committee makes the following recommendation for the purpose of enhancing the vital role of the 1890 institutions as providers of access to underrepresented segments of the population and important contributors to food and agricultural systems research.

RECOMMENDATION 12. *The federal government should require that states match formula research funds going to 1890 institutions in the same manner as is required for 1862 institutions.*

The committee recognizes the possibility that a few states may refuse to match the federal funds; it feels, nonetheless, that the time for this recommendation has arrived. If political processes within the states do not bring about a state match, and some 1890 institutions consequently lose their federal formula funds, it could mean the loss of 80 to 100 percent of these colleges' research funding base. Recognizing this potential consequence forces the question of whether, for example, having a system of 15 well-funded 1890 institutions is better or worse than having a system of 17 inadequately supported institutions.

Public-Private Partnerships in Research Funding at LGCAs

Until the 1970s, funding by private industry of research at most land grant colleges of agriculture was comparatively rare. By the 1980s such funding had become more common. In the 1990s private industry funding is accepted and even encouraged by administrators and by federal policy. A growing amount of private funding comes from diffuse end users, such as dairy farmers who support research with checkoff funds. The following five factors contribute to increased funding by private industry at colleges of agriculture.

1. The cost of research has risen faster than general inflation because of, for example, costs related to complying with regulations, use of more sophisticated equipment, and complexity of problems tackled.
2. The number of researchers in colleges of agriculture has grown slightly over the past 25 years, even in the face of downsizing tenure-track positions at many institutions and eliminating many departments in, for example, poultry science, dairy science, horticulture, and entomology.
3. Federal and state funding for agricultural research has not grown nearly as rapidly as the costs of doing research, leaving a considerable deficit that necessitated downsizing and turning to alternative sources of funding.
4. Private industry needs the kinds of expertise and equipment found at LGCAs, and often it is much less expensive to use these than to duplicate them, particularly for sporadic needs.
5. Private industry has resources for research not always available to any given land grant university, such as specialized equipment, expertise, animals, and capital.

During the 1980s there was considerable discussion by all universities about using public facilities for research conducted with private funding. Efforts were made to deal with issues like patenting, licensing, consulting, publication rights, royalties, and conflict of interest. Although such funding is now widespread, most is in the form of simple contracts between industry and universities without any direct financial remuneration to university scientists other than as a potential source of funds to pay their university-mandated salaries. There are, however, instances in which university scientists become part owners of start-up companies, leading to more direct potential conflicts of interest. Surprisingly, even this degree of involvement of university scientists generally is reasonably well accepted. This is in part the result of efforts to deal with potential conflicts before contracts are finalized and to keep the process open to public scrutiny. Even so, the following concerns remain, especially on the part of some constituencies.

- Does the university really benefit sufficiently—for example, are overhead charges and royalties high enough?
- Does this kind of activity taint objectivity of university scientists?
- Is a larger-than-desirable infrastructure being maintained, resulting in, for example, training artificially high numbers of graduate students in some fields?

CHECKOFF FUNDS

One method of funding research needs of diffuse end users, such as soybean or hog farmers, is a self-assessment mechanism known as checkoff funding. These commodity checkoff programs are established by authority in either federal or state legislation to be used for research and promotion. A referendum requiring two-thirds or majority approval by voting producers is required in federally mandated programs. Some state programs, however, do not require referendums. Some programs have a refund provision when producers request funds within a given time period. Some of the federal programs include provisions that a percentage of funds remain in the state where funds originate to be used for programs of research and promotion that might meet needs of that state or region.

The primary objective of most checkoff funds is to promote marketing of the commodity but nearly all have research components, even if only to evaluate the effectiveness of the promotion. One great advantage of checkoff funding mechanisms is that those funding these programs set criteria for research and promotion.

There also are many perceived benefits of industry-university collaborations in addition to maintaining funding levels and, thereby, avoiding marked downsizing. These include

- more efficient use of intellectual and other resources from a societal standpoint,
- opportunities for students to experience some aspects of working in industry,
- more rapid movement of graduating students into appropriate first positions and the resulting more rapid and efficient recruitment to fill industry positions, and
- incentives for "intellectual engines," like start-up companies, that in turn foster whole industries, like biotechnology.

Clearly, industry-university relationships have strengthened lately, particularly in food and agricultural sciences, and this trend may accelerate. Those who make decisions about federal funding of agricultural research will continue to face two broad realities: (1) the private sector is providing considerable resources for agricultural research at public institutions; and (2) federal legislation can have significant effects on such arrangements by, for example, providing tax incentives to support these activities.

With these realities in mind, the committee concludes that public policy must be flexible enough to ensure that private resources can be used to leverage public support for agricultural research when that research is consistent with federal goals. At the same time, continued vigilance is needed to avoid conflicts of interest in such research support, and this is best dealt with by having policies and procedures that, as much as possible, prevent problems before they start.

The committee further concludes that a more in-depth look at public-private partnerships, including publication rights, royalties, and patents, is needed. In conjunction, the implications for objectivity, academic freedom, and the types of research conducted with public funds is an important area of further study.

Alternative Mechanisms for Allocating Competitive Grants

Refining the federal-state partnership to address (a) the equity and efficiency of allocating federal funds for agricultural research, (b) priority setting and stakeholder involvement, and (c) public-private partnerships in agricultural research is constrained by the limited number of mechanisms used to provide federal support. An examination of alternative mechanisms may reveal new opportunities for the land grant system and its federal partner and complement the recommendations for change the committee has made with regard to specific elements of the agricultural research system.

At present, federal funding for extramural agricultural research is provided as formula funds, special grants for specific projects and institutions mandated by Congress, contracts, and competitive and peer-reviewed grants. Lesser-used mechanisms include cooperative agreements, small-business innovation research (SBIR) grants, and collaborative research and development agreements (CRADAs) with private industry. Although the variety of mechanisms suggests considerable flexibility, the system is, in practice, rather rigid for individual scientists or groups of scientists with a new, meritorious idea for research. This is true even for scientists who have experiment station appointments. A range of seldom-used alternative mechanisms does, however, exist, particularly in the design of competitive grants programs.

Preproposals

One way to reduce the paperwork and time consumption associated with processing competitive grant applications is to institute a preproposal step. Applicants would submit brief (2 or 3 page) preproposals for evaluation; the most meritorious would then be eligible for further consideration as full proposals. For example, if funding is available for 100 grants, only the most promising 200 to 300 preproposals would be eligible for resubmission as a full proposal. This would greatly decrease time spent on both proposal preparation and evaluation. Furthermore, this system can relatively quickly sort out proposals that do not fit subject matter criteria or are from unqualified investigators.

A related approach being tested in some NIH study sections is a system of triage. On receipt, standard competitive proposals are briefly evaluated by small committees, and the weakest one-third are rejected. This saves time because only two-thirds of the applications are fully reviewed, and the other one-third of applicants know of a nonfunding decision quickly rather than after the usual 6 months required for full evaluation. This permits rewriting and resubmission for the next round of funding, which is every 4 months at NIH.

Chunk Grants

Another mechanism used by some agencies, and under consideration by others, is the "chunk grant," in contrast to conventional full resource-recovery grants. Chunk grants might be for $50,000 per year for 2 or 3 years or might take the form of separate competitions for, for example, $20,000 or $50,000 portions of larger grants. With this scheme, the number of grants to be given is predetermined—hypothetically, 200 $100,000 grants; there is no negotiation over precise budgeting, budget justification, or overhead charges. Within the proposal there still might be considerable explanation of how funding would be used, but it is a much simpler approach and allows the investigator to allocate funds as deemed necessary.

Another appeal of this method is its honesty. Researchers cannot accurately predict what their precise financial needs will be 3 or 4 years after proposal preparation. Chunk grants and separate competitions eliminate the need for future-oriented guesstimates, and there still would be oversight and auditing to ensure funding is used legitimately.

Some perceive a considerable fringe benefit from such grants in that many investigators would be quite productive with $50,000 per year. This approach could ultimately

result in funding more investigators who devote less time to developing proposals with low probabilities of funding.

Percentage Funding

One method of increasing the distribution, though not necessarily the efficiency, of funding is to fund proposals for only a percentage of the amount requested. This has frequently been used by NIH study sections, funding all proposals at 75 percent of requested amounts, which results in funding 33 percent more proposals.

A variation is to fund by merit percentile. For example, if funding is available for 10 percent of applications, funding is instead allocated to the most meritorious 20 percent of proposals. Of those funded, the top one-third might be funded at 70 percent of funds requested, the middle one-third at 50 percent, and the bottom one-third at 30 percent (each representing about 7 percent of proposals submitted). This might work especially well for chunk grants, allocated at $70,000, $50,000, and $30,000 per year, depending on rating.

The major objection to this approach for conventional grants is that researchers may not receive the resources needed to do the proposed work well or that they may be encouraged to inflate their anticipated research costs.

Performance-Based Funding

Performance-based funding mechanisms have also been advocated. For example, established investigators with a good track record could count on a given amount of funding annually as long as they remained productive, as determined by broad peer review of their publications and the performance of their trainees. This is pretty much the basis for selecting and maintaining investigators funded by the Hughes Foundation. Funding by the Medical Research Council in the United Kingdom is partially based on this system. This approach, though criticized by some as elitist, is effective in getting good research accomplished; and funding is terminated when performance slips. Although the number of individuals funded usually is limited, this approach is only a small variation from methods used to fund centers or institutes.

Another proposed method of performance-based funding is to pay by the paper (or report) produced. An excellent paper might be worth $20,000, a good one $10,000, and a fair one $5,000, with no funding for mediocre papers—all evaluations, of course, determined by unbiased peer review.

Summary

All of these systems have advantages and disadvantages. As a balance is sought among independence, excellence, security, fairness, getting the most relevant research per dollar, and considerations of training personnel and extension benefits, it becomes clear that a palette of funding mechanisms is desirable. In some cases, two or more mechanisms might be the best option, even within a program. For example, within the USDA competitive grants program, with sufficient resources, there may be room for chunk grants and performance-based funding of centers in addition to the current full resource-recovery competitive grants.

The committee believes USDA could experiment more extensively with alternative mechanisms for the allocation of federal research funds. Pilot projects of selected mechanisms could be established and evaluated, with evaluation focusing on compatibility between private and public research funding, the opportunity cost of grant application, administrative efficiency in competitive granting processes, and compatibility with more explicit research agenda-setting and prioritization processes.

Funding Interdisciplinary and Multidisciplinary Research

The committee believes there is a special case to be made for mechanisms of funding inter- or multidisciplinary research, such as special divisions of competitive grants programs. The need for multi- and interdisciplinary research is great, but the following problems arise.

- Interdisciplinary work can be difficult to initiate because researchers in different fields must learn each others' languages and cultures. It may take a year or more just to frame hypotheses and develop methods to test them. Some have advocated $20,000 proposal preparation grants for these situations.
- Giving appropriate credit to the individuals involved may be complex, affecting salary, promotion, and tenure decisions or professional recognition. The contributions of young investigators, particularly, may be difficult to discern, especially on papers authored by five or more scientists. Young people have difficulty establishing their own reputations in these settings and are often advised to avoid such involvements early in their careers.
- Multidisciplinary proposals are more difficult to evaluate than monodisciplinary proposals because with multidisciplinary proposals experts from various areas must be able to integrate dissimilar information. Typically, multidisciplinary proposals fare badly in competition with proposals that are simpler and easier to evaluate by traditional peer-review panels.
- Multidisciplinary proposals tend to be long-term and expensive, often equal in length and cost to several more conventional grants. Peer reviewers tend to prefer to fund three grants rather than only one. Also, because of their long-term aspects, results of such research are unavailable for years, making evaluation and funding of renewals additionally problematic.

Despite these challenges, the committee believes there is a strong case to be made for enhancing opportunities through competitive grants programs for inter- and multidisciplinary research, particularly at the integrative research stage in the research continuum. Consequently, the committee strongly endorses

- special divisions of competitive grants programs designated for inter- and multidisciplinary projects and the use of interdisciplinary peer-review panels and processes;
- an emphasis on multi- and interdisciplinary programs by federally supported regional centers and multi-institution consortia (see Recommendation 3); and
- an emphasis on inter- and multidisciplinary projects and programs supported by combined federal formula funds for research and extension (see Recommendation 4).

CONCLUSIONS

The past accomplishments of agricultural research conducted at the land grant university colleges of agriculture provide no rationale for maintaining the status quo in the face of new research needs and paradigms and a rapidly changing operating environment. The recommendations made by this committee in this chapter are aimed at capitalizing on lessons learned from science policy on a broader front and at recognizing the expanded public mandate that now affects the system and its accountability.

The high rates of return on the public's investment in agricultural research and extension (estimated to be between 30 and 50 percent) provide compelling evidence that the institutional structures that have characterized the LGCA research system have served the nation well, including the mandate to link research to public needs through extension, the federal-state partnership, and the institutional base of support in the form of formula funding for research and extension. Nonetheless, in light of changes in society's interests in food and agriculture, new opportunities in science, developments in science policy, and fiscal realities, some important changes in funding policy should occur. In particular, there should be an enhanced role for competitive grants programs and merit-based review. Enhancing the role for these mechanisms would make it

possible to capitalize on new opportunities in food and agricultural system science, to amplify the quality of research, and to draw on the large pool of scientific resources beyond the experiment station. At the same time, formula funds can continue to be an effective means of research support. In addition to supporting long-term applied research needs of particular crops, livestock, and regions (National Research Council, 1989), formula funds support the unique aspects of land grant research, particularly the linkages to public needs through extension.

Nonetheless, the committee feels, as evidenced by the recommendations in this chapter and in Chapter 2, some important changes should occur in the use and allocation of formula funds. In particular, these funds should be used more creatively and innovatively to enhance the integration of research, extension, and teaching in the spirit of the land grant philosophy and mandate and to promote multidisciplinary approaches that are strongly needed in food and agriculture (Recommendation 4). Additionally, experiment station scientists and extension service specialists who are beneficiaries of formula funding should be encouraged to collaborate with and draw on the scientific resources and knowledge beyond the colleges of agriculture; formulas should be reconfigured to reflect the contemporary spectrum of food and agricultural research and extension issues and beneficiaries (Recommendation 11); and, in the interest of equity and the importance of serving limited-resource producers and consumer groups, states should be required to match federal formula funds to 1890s in the same manner as required for 1862s (Recommendation 12).

5

Extension

Cooperative Extension (extension) was designed to link land grant college programs, grass-roots needs, and national priorities. Its implementation completed the tripartite mission of the land grant college system and made the land grant model a unique concept in higher education. The three-way partnership among the federal government, the states, and the local communities was established to enable the delivery of new technologies to the farm and to relay farmers' needs to the university researcher as well as teach technical and self-enhancement skills to farm and rural youth; and it has helped rural households and communities meet their daily economic challenges and cope with changing times (Rasmussen, 1989). Although the distinction is not always clear, university extension, conversely, is more often focused on continuing education for graduates and members of the community and it is often fee-based.

Today cooperative extension faces many challenges but also considerable opportunity. Its critics argue it is spread too thin both spatially and substantively. Satellite training, Internet access, CD ROM, and videos have supplanted bulletins, brochures, and meeting presentations—the traditional media of cooperative extension. Furthermore, it is often not on the cutting edge of research, and many if not most of its programs do not have a broad base of support outside its traditional circle of clientele. At the same time, new information technologies offer opportunities to enhance the efficiency of extension delivery (Hildreth and Armbruster, 1981). Growing incentives for private consulting in the farm sector means that, where incentives for the private sector are lacking, extension can put more emphasis on programs with broad public benefits and on clientele with limited means to pay. The large number of public issues and informational needs that relate to the food and agricultural system exemplifies the continuing need for a system dedicated to linking science to the national interest.

Several issues important to extension, and accompanying recommendations, were discussed in Chapter 2:

- the potential for designing extension programs to create a new geography through regionalization, distance learning, and multistate collaborations;
- the diversity of producer and other clientele groups, and how extension along with research must—drawing on broad stakeholder input—more carefully assess the differing needs of these diverse groups;

HOW IS UNIVERSITY EXTENSION DIFFERENT FROM COOPERATIVE EXTENSION?

- University extension at the University of Washington and the University of California at Santa Cruz fits the model of a continuing education program for college graduates. UC Santa Cruz Extension, for example, serves people with average annual incomes of more than $40,000, many of them interested in retooling or midcareer development. It offers formal instructional courses for credit and no credit. Unlike cooperative extension, university extension is not designed to reach underrepresented communities or to solicit grass-roots input regarding educational and research needs.

- the role of public research and extension in relation to these different groups and the need to target and prioritize programs accordingly;
- the importance of and potential for reforging links among research, extension, and teaching; and
- the need for meaningful performance indicators for extension (as well as teaching and research) and the need for more critical review and evaluation.

In this chapter the committee reviews the continuing national interest in the extension component of the land grant university's tripartite mission and the federal government's role in advancing the national interest. Focused on are two controversial issues: (1) the growing privatization of agricultural extension and (2) extension's nonfarm (or nonproduction) programs. The committee also discusses and makes recommendations regarding the allocation of federal extension funds.

THE NATIONAL INTEREST IN PUBLIC ACCESS TO FOOD AND AGRICULTURAL KNOWLEDGE AND RESEARCH

The interface between the food and agricultural system and global and national well-being is extensive and complex. Involved are food needs and human health, economic performance and competitiveness, environmental quality, and sustainability of the natural resource base. Such complexity calls for a well-knit articulation of food and agricultural research and societal goals. Cooperative extension, as the interface between the university and the people, has an important continuing role in assuring that the conduct of related sciences is in the national interest.

Extension shares this role increasingly with the private sector; however, publicly financed extension remains in the national interest for three main reasons.

1. First, a publicly supported extension service can assure that food and agricultural and related scientific research translate into practical applications and new technologies with broad-based public benefits.
2. Second, extension can help guarantee that information that influences public policy and private decisions regarding the food and agricultural system (and its interface with human health, natural resources and the environment, and economic performance) is widely accessible, accurate, and science-based.
3. Third, extension can play an important role in assuring that all peoples' problems and needs (not just those of people who can afford to pay) are relayed to research

planners and translated as appropriate into research priorities and in coordinating and enhancing the interactions of diverse participants in the food and agricultural system.

Over the decades, external developments have changed and are changing cooperative extension's role in linking university knowledge to peoples' needs. Many of these changes are discussed in this chapter or in Chapter 2. At the same time, internal developments at many land grant universities may have heightened the importance of the extension component of the tripartite mission in completing the research continuum from discovery to application. The trend at many, particularly the larger research, universities has been toward fundamental, discipline-based research—a trend driven by federal research grants programs, by the strong justification for federal financing of basic research, and by the growing role of private firms in conducting some types of applied research. If extension is well integrated into the research process—at the earlier as well as later stages of the research continuum—and in touch with public issues and clientele needs, it can contribute importantly to the articulation of fundamental knowledge, practical applications, and public priorities.

Today there is a strong national interest in ensuring that the public receives accurate information about the agricultural and food sector with which to make well-founded decisions about issues that affect everyone. These issues include land use, water rights and allocation, environmental regulation, new technologies, and food safety standards. In fact, during the committee's public forums (held in the spring of 1995), one of the most-often heard comments from extension's traditional farm and ranch clientele was the desire for more assistance from extension in understanding the multiple federal laws and regulations that affect their use of land. Some suggested that extension can act as an information clearing-house with respect to the rules and regulations of multiple federal (and presumably state) agencies. May be because of the frustration regarding the goals and workings of government regulations, seemingly growing animosity toward federal agencies is of concern today. The extension service can be an effective liaison between public and private actors in the agricultural and food sectors by disseminating and interpreting information, conducting discussion groups and seminars, and relaying information back to federal agencies regarding the impacts of federal laws and regulations.

The literature suggests that the return on the public's investment in extension, as measured by its impact on farm productivity, has been substantial, although estimates vary widely (Evenson, 1979; Huffman, 1976; Huffman and Evenson, 1993; Huffman and Miranowski, 1981; Yee, 1992). The recent work of Huffman and Evenson (1993) suggests a rate of return on extension investments of approximately 20 percent, which is lower than for research. However, another set of studies, including work by Huffman (1976), Huffman and Miranowski (1981), and Evenson (1979), found rates of return on investments in extension of between 82 and 110 percent. And Yee (1992) estimated parameters of an econometrics model that translate into rates of return on the order of 100 percent. Evenson (1979) also found that a farm management research/extension component had the highest marginal return among the categories considered in analysis of research categories.

There are particular challenges to estimating returns on extension investments, and these challenges limit the usefulness of the above estimates in assessing extension's impact. A large share of extension funding is today allocated to human, family, and community development and nutrition education. The benefits and costs of these nonfarm extension programs are not included in the studies cited above, which focus on the impacts of agricultural extension on farm productivity. To do the needed analysis of returns on the public's investment in all extension activities, other measures of program performance must be identified and related to program investments (see Recommendation 13). The need for extension performance indicators was underscored in Chapter 2 in the discussion of accountability.

THE ORIGINAL ROLE FOR THE FEDERAL GOVERNMENT

When the nationwide extension system originally began to evolve, it did so without federal assistance. Some states started extension departments at the land grant colleges and some counties hired extension agents. A national initiative was needed, however; first to put the system in place in large states with small populations (like Montana) and, second to ensure a coordinated, effective system with a nationwide impact. The effort to develop a national system was given tremendous impetus by President Theodore Roosevelt's Commission on Country Life, which included Liberty Hyde Bailey, a founder of Cornell's College of Agriculture and Life Sciences and nationally recognized for his research in horticulture and botany and his commitment to making research results available to farmers. The commission recommended (Rasmussen, 1989: p. 44) that

> each state college of agriculture should organize as soon as practical a complete department of college extension. The work should include such forms of extension teaching as lectures, bulletins, reading courses, correspondence courses, demonstration, and other means of reaching the people at home and on their farms. It should be designed to forward not only the business of agriculture, but sanitation, education, home making, and all interests of country life.

As it took its final form in Smith-Lever legislation, the uniqueness of the nationwide extension system was its coordinated partnership among county, state, and federal governments (therefore "cooperative" extension). The Smith-Lever Act provided a systemwide purpose for extension: "to aid in diffusing among the people of the United States useful and practical information on subjects relating to agriculture and home economics and to encourage the application of the same."

THE FEDERAL ROLE

The federal government's initial role was to help put the cooperative extension system in place, to assure nationwide effectiveness, and to identify national needs. Over the decades, as the extension system matured, the federal role in financing extension decreased significantly in relation to funding by states and localities (National Research Council, 1995a). Total federal funds for extension were $439 million in FY 1995. This represented 29 percent of all cooperative extension funding from state, local (including county and private), and federal sources, down from 42 percent 20 years ago (National Research Council, 1995a). In some states the federal share is significantly smaller, although there is a large variation. State and local government funds are more important today than in the past. Private sources of funds, including corporate support, grants by nonprofit organizations, and fees for service, are also increasing in importance at the same time that there is a growing role for the private sector in providing extension services. Congressional stipulations governing the use of federal extension dollars have also increased, particularly to reorient extension toward the interests of urban and other nontraditional extension clientele.

Important Roles for the Federal Partner

If extension is a bottom-up system responsive to local needs and delivering local benefits, why should the federal government be involved? Certainly one of the main original reasons—that big states with small populations needed help in getting extension

up and running—is no longer valid. The committee believes, however, that there are important, well-targeted roles for the federal partner.

One of the most important roles is that of contributor to the funding of those extension programs that provide public goods that cross or transcend political boundaries. These programs lack the impetus of incentives for private funders, and states will tend to underfund such programs because their own producers and taxpayers cannot sufficiently appropriate the benefits.

Programs that introduce new technologies or management practices that reduce off-farm environmental damage often have these transboundary, public-good qualities. Environmental problems are often regional in nature because aquifers, rivers, soil, air, and smoke do not respect state lines (U.S. Congress, 1995). Additionally, broadly applicable technologies often "spillover" rapidly to the benefit of producers in other states and even other nations, and so their adaptation and dissemination tends to be underfunded by both the private sector and states. In this context, the federal partner can help the system realize considerable gains in efficiency by providing the incentives for states to engage in regional and other collaborative extension efforts (see Recommendation 3).

A second important role is that of financial supporter of those programs that provide public benefits where the constituency at the state and local levels lack economic means and political effectiveness. Human nutrition education is a good example because those most in need are economically and politically disadvantaged. The benefits to society of improving the nutritional status of infants and children and pregnant and lactating women, however, are well recognized and include reduced infant mortality, reduced health care costs, and improved development and learning abilities (National Research Council, 1994b). Another important function of such programs is providing marketing information and analyses for low-income and small-scale (such as many niche-market) farmers—clients who are typically unable to conduct such analyses on their own. They are, nevertheless, important providers of direct-marketed fruits and vegetables and other specialty products—a growing demand of U.S. consumers.

A third important role is that of a leader in reforging linkages between extension information and education, on the one hand, and land grant university research on the other. The federal government initiated the components of the land grant system—teaching, research, and extension—in separate phases: as each was implemented, it became clear that the next was needed. Despite the recognition that it was the integrated complex that was important, the separate pieces of legislation spawned separate funding systems and separate administrative structures. Agricultural research and extension have understandably diverged over the years for many reasons related to both internal and external forces. If extension of the future is to have the key place in the land grant model that it was meant to have, efforts must be made to mend the link, and the committee believes the federal government can and should have an important role in doing so (see Recommendation 4).

A fourth major role for the federal government involves ensuring accountability and equity in the use of federal funds for extension programs. This can be done by leading the way and working with state extension services to develop performance measures and standards (see Chapter 2 section, Accountability and Funding Principles).

A fifth and related role is that of acting as a national repository for data and information on extension programs; such a repository should benefit both extension users and extension suppliers. The data reporting system for public extension expenditures has been both less systematic and less accessible than that for research expenditures. Additionally, extension spending categories have changed significantly over time, making it difficult for users and analysts (as well as extension administrators) to assess changes in resource allocation (Fuglie et al., 1996). In the role of national repository, the federal government can assure that effective, successful programs at the regional, state, and local levels receive national recognition and, where appropriate, become national models.

RECOMMENDATION 13. *Data on extension projects and programs, goals, and outcomes should be compiled and organized more systematically to enhance their usefulness to extension administrators and clientele and to aid in analyses of the returns on public investments in farm and nonfarm extension programs.*

Who Is the Federal Partner?

The U.S. Department of Agriculture has been extension's federal partner, and as such, the committee encourages USDA to exercise leadership in drawing other federal agencies into support for and leadership of extension programs. The food and agricultural system is interconnected with human health and safety, environmental quality and natural resource management, energy sources and security, and human, community and economic development. Thus other federal agencies, including the Environmental Protection Agency, the Department of the Interior, the Department of Energy, the Food and Drug Administration, and Health and Human Services, have inherent interests in the effectiveness of extension programs and should have a larger presence than they currently do if, in fact, these are programs that serve the national interest. Extension's federal partner has an opportunity to enhance communications between the federal research establishment and diverse federal initiatives in a variety of departments and to tie these to consumer needs and clientele concerns (see Recommendation 16). The committee hopes that the federal partner will accept the challenge to take on a stronger, more viable role in cooperative extension.

EXTENSION'S ROLE IN THE MODERN CONTEXT

The context of the national condition is very different than it was at the time the base for extension was laid. Transportation networks are rapid and extensive and there have been major revolutions in communications systems technology; thus, at the same time that the nation has become increasingly connected and urban and suburban, farms and rural communities have become much less geographically isolated, and farm households are not nearly as different from nonfarm households as they used to be. Education and income of farm households is, on average, on a par with the education and income of nonfarm households (Dacquel and Dahmann, 1993). Many farmers and their families are well educated—often by the colleges of agriculture—and so have excellent connections to them. Most farm families include members who work off-farm, in local towns and cities; in fact, almost 80 percent of U.S. farm households have more off-farm than farm income (National Research Council, 1995a). Nonetheless, rural areas have a disproportionately high share of the nation's low-income communities and are engaged in constant struggles to secure an economic base for their futures (U.S. Department of Agriculture, 1994).

The farm itself is very different than it was in the past, although a wide range of types of farms exists. The farms that account for the majority of agricultural products entering commercial markets are highly sophisticated organizations operating with cutting-edge production and information technologies. In fact, many large operations—particularly in the more industrialized and vertically integrated sectors like poultry and vegetables—can and do conduct their own applied research. They have the capacity, operations, resources, and knowledge base to do so.

Farms are also different today in that their operation is based on a wider range of professional sources of information and technical knowledge. Input manufacturers and suppliers as well as agronomic consultants deliver, for example, advice, testing, and scouting services to farmers on a fee-for-service basis. Farmers subscribe to or have access to a variety of farm-related trade publications, reports, and on-line services that contain production information, economic intelligence, and analyses provided by government agencies and consulting firms (Kalaitzandonakes and Bulloch, 1995; Wolf, 1995). These external changes—in part the result of decades of successful extension programs—pose significant challenges, but also opportunities, for cooperative extension.

ORIGINS OF COOPERATIVE EXTENSION

Conditions in the United States in the early years of the land grant colleges provided the justification and impetus for a nationwide cooperative extension system. Not only was there a large farm population, but farm and rural households had unique characteristics and needs. In addition to producing commodities for the market and managing farm and household finances, farm families were often largely self-sufficient economic units. They made many of their own farm and household items and produced, stored, and processed their own food. Farm families were often geographically dispersed and isolated. Transportation and communications were slow and still poorly developed in the late 1800s in many parts of the country. Most farmers were not likely to have the time or inclination to make special trips to the colleges to seek advice or attend special classes.

During this same period, colleges of agriculture were in need of a constituency and base of support to secure their future. Farm population as a share of total US. population declined from about 50 percent when the colleges were initiated in 1862 to about 35 percent in 1910, the year in which the absolute number of people living on farms peaked (National Research Council, 1995a). The majority of college students were already headed for confirm jobs and other ways of life; thus, students did not necessarily provide a strong link back to the farm. Additionally, among farmers there was widespread suspicion of what was referred to as "book farming" (Reassumes, 1989).

The loss of farm population after 1910 was noted and of some concern to national leaders. Followers of Theodore Roosevelt's Progressive Party (1912), in particular, expressed the need to ensure that farm output could and would keep pace with the country's rapidly expanding population and that food and fiber would be abundant and reasonably priced in cities and towns. This national concern with food security, combined with the needs of farmers, created the demand for agricultural extension. Initially, a number of approaches were tried that were not exactly right for agriculture. For example, extension courses were offered at the colleges, and "farmers institutes" were established, which provided educational facilities locally at places farmers could reach. However, it tended to be farmers most in need of university knowledge and assistance that were least reached by these approaches, often because they were the least able or likely to make the effort to participate. Many believed that extension needed to go to the farmer and not wait for the farmers to come to the college or selected off-campus sites (Reassumes, 1989).

Challenges and Opportunities for the Future

First, the improvements in transportation and communication networks, coupled with the widespread awareness of extension among agricultural clientele and the higher education levels of that clientele mean that there are opportunities to reconsider delivery points for extension services and to use advanced delivery technologies such as telecommunications and computer networks. The geography of extension can be very different than it once was—crossing political boundaries and being more attuned to the "market" in which a product or service of the land grant university can be applied (see Recommendation 3).

Second, the existence of a private sector role in providing technology, information, and advice to farmers means that public extension can redirect its efforts toward those areas where private incentives are lacking. Extension must complement rather than compete with the private sector.

Third, a significant challenge stems from the changing structure of the farm sector. Large, commercial farmers increasingly seek (as comments offered at the committee's public forums suggest) a more direct connection to university-based specialists. These farmers report that the county agent is often too much the "generalist" for their highly specialized needs. At the same time that many large commercial farmers are seeking more direct access to the most up-to-date university science, many smaller and "alternative" farmers feel that their needs are not sufficiently met by current county-based extension efforts. Industrialized, or vertically integrated, agriculture poses other issues for extension. Farmers contracting with vertically integrated firms may have little flexibility in choosing how to produce the goods in which they specialize. The seed, animals, or feed used for production may be owned by the integrating firm, which has its own technical and professional staff that can provide extremely context-specific information based on proprietary data to which extension has no access. For example, improved genetics, feed rations, building technology, and on-site consulting have all been packaged in hog contracts (Kalaitzandonakes and Bullock, 1995).

Finally, in a country of few farmers and many consumers—and where the population is predominately urban and suburban—extension finds itself struggling to balance its responsiveness to farm, rural, urban, and suburban needs. Many believe relevance to the nonfarm—and nonrural—clientele is essential to support for extension's future but that the traditional base of support should not be lost either. Extension must be relevant to modern society; however, it cannot be all things to all people.

Private versus Public Roles in Agricultural Extension

The private sector has a growing role in food and agricultural technology transfer and information dissemination. The word "privatization" used in a broad sense means introducing or increasing private sector participation, as opposed to meaning only a transfer of public assets to the private sector. In the broad sense, significant amounts of privatization have occurred both in the United States and other nations.

As a result of budgetary pressures, many countries have examined alternative arrangements for delivery of extension services, including public expenditure reductions, changes in approaches to generating tax revenue, charges for government extension services, commercialization and privatization (Howell, 1985). According to Le Gouts (1991), three principal policies have been followed by governments: (1) public financing by the taxpayer only for the kinds of services that are of direct concern to the general public, (2) direct charging for some individual services with direct return such as improved income, and (3) mixed funding shared between public and private professional association contributions for some services where the benefits are shared (Le Gouts, 1991).

Some governments have gone considerably further. New Zealand's Ministry of Agriculture and Fisheries' agricultural advisory service, having introduced the user-pays philosophy in 1985, now operates as a self-supporting commercial consultancy business fully owned by a private firm—Wrightson LTD (Retch, 1995). The Netherlands has privatized about one-half of its public extension service by transferring field staff to farmer associations, where initially they receive government financial support. The extension components and staff responsible for linking research and the privatized services, policy preparation, implementation, and regulatory tasks have remained under the Ministry of Agriculture (Le Gouts, 1991). Dutch farmers pay for extension partially through membership fees to farmer associations. In Chile, vouchers distributed by the government allow farmers to purchase private extension services. In the Australian state of Victoria, a form of privatization has been proposed (Cary, 1993).

The United States has much to learn by examining these and other nations' experiences. Clearly, a considerable amount of privatization of agricultural extension has taken and is continuing to take place in the United States. As discussed above, US. farmers purchase advice along with inputs, they hire private consultants, and they subscribe to informational services. Additionally, contract employees of integrated firms and owner-operators of large commercial entities often use proprietary technologies, such as genetically engineered crop varieties that have been developed by the firm, and are provided internal technical advice regarding the management of these resources to meet company specifications for the end product (Postlewait et al., 1993).

The committee believes that the increasing role of the private sector in information and technology transfer is particularly welcome in an era of budget tightening and increased efficiency in the use of public funds. However, the committee is also concerned that the efficiency gains that can accompany "privatization" of extension come also with equity implications. As discussed in Chapter 2, the US. production sector is highly concentrated but also contains large numbers of small- and medium-scale, limited-resource, alternative, and niche-market farmers. This group of producers may have much less opportunity and far fewer resources to purchase information and technical advice and less internal knowledge of environmental and public health standards and means of meeting them. Public extension must have a continuing and important role in assuring access by these farmers to knowledge regarding farm technologies and agronomic practices, such as biological control and crop rotations, and to information on market opportunities, financial strategies, and public policies. In fact, consistent with Recommendation 2, it is particularly important for public extension to seek out and target those producer groups most in need of extension and least able to pay; it is this effort that would truly reconnect today's agricultural extension service to its original mandate.

Indeed, the full spectrum of producer groups, types, and sizes needs adequate public support in order to maintain diversity in agricultural production during accelerated rates of agricultural industrialization. Uniformity in plant or animal genetic stock, in production practices, or in approach to production can make a biologically based sector that, like farming, is subject to the vagaries of weather, disease, and pests, extremely vulnerable. Small-scale and limited-resource farmers are important contributors to the diversity of approaches, practices, cultivators, and animal stock in US. agriculture. Furthermore, it is to a large degree the small-scale and part-time producers who fulfill the demand for direct- and niche-marketed farm and food products.

Extension funds provided to 1890 Lucas, according to a NASULGC (1995) report, have been prioritized to educational initiatives designed to address "new pathways" for a large at-risk audience generally out of the mainstream of society's opportunities. Federal extension funds specifically for the 17 1890 colleges total $25.5 million (about 5 percent of total federal funds for extension); these federal funds, unlike those allocated by formula to 1862 institutions, do not require a state match. In fact, state support of 1890 extension programs totals $1.25 million, or less than 5 percent of federal extension funding; and several states with 1890 colleges provide them no extension support at all (Ellen Danes, 1996, USDA, Cooperative State Research, Education, and Extension Service, personal communication). The lack of matching funds means that extension programs specifically targeted to the needs of limited-resource farmers and low-income communities have fewer resources than other extension programs. The committee offers the following recommendation with the expectation that it will expand resources for extension programs directed to the information and technology needs of limited-resource farmers and low-income communities.

RECOMMENDATION 14. *The federal government should require that states match formula extension funds going to 1890 institutions in the same manner as required for 1862s.*

Complementarily between Public and Private Extension Providers

During the committee's public forums, some college of agriculture clientele expressed support for public agricultural extension based on their belief that it is a neutral source that can validate other sources without bias. As the private component of extension services expands, there may indeed be a particular need for public extension to increasingly play the role of an unbiased arbiter of private services and advice.

In some states input suppliers and private consultants have become a significant source of direct information for commercial farmers; however, these private providers often obtain their information from university extension specialists who offer special on-site or university-based training for both public extension agents and private consultants. One way to look at this relationship is to see extension personnel as wholesalers of technical information and private consultants as, increasingly, the retailers (Feller et al., 1987).[1] In the wholesaler's role, the extension specialists' connection to the university and its research base (in fact, extension specialists are often researchers, too) gives them a unique advantage—specialists may maintain laboratories to identify diseases and insect pests and may be national experts on generic problems such as the treatment of particular diseases, while their private sector coworkers provide in situ testing of the specialists' research theories. Extension advisors or specialists frequently collaborate with farmers or use university plots to test product samples supplied by seed and chemical companies (Postlewait et al., 1993). Opportunities for complementary roles between public and private providers of extension services should be welcomed and pursued, particularly if the public sector can fill a unique role that private providers cannot.

Despite the growing and important role for the private sector in providing technical advice to farms and agribusiness, the private sector will not adapt and disseminate the full range of university knowledge and findings of importance and benefit to all participants in the food and agricultural system. For example, the private sector has insufficient incentive to transfer agronomic management practices and technologies that reduce off-farm pollution (unless these technologies can also be shown to increase short-term returns to producers). This is because even though the social benefits of such improvements may be high, farmers and private firms cannot capture those benefits in the form of higher profits.

Roles for which Extension Is Most Qualified

Extension has had an important role in advancing the adoption of ecologically based pest management strategies, such as integrated pest management (IPM) (National Research Council, 1996). Ecologically based pest management strategies are a "risky" innovation for many farmers (because of the uncertain impact on profit); it is, nevertheless, an important means of reducing dependence on chemical pest-control methods by integrating chemical controls with biological controls, scouting, and cultural methods. A study by NAPIA et al. (1988) found that frequency of contact with extension was positively and significantly correlated with adoption of integrated pest management systems in four of the nine states included in their study. According to Postlewait et al. (1993:p. 284), extension advisors "are the major promoters of integrated pest management and sustainable agricultural programs, especially at the early stages before these programs are

[1] In a 1991 speech, Alex McGregor, president of The McGregor Company (an agricultural research and agronomic advice firm), notes, "… nine county extension agents serve the 150 mile radius within which The McGregor Company operates. In the same geography, our firm alone has 75 field consultants trained by three company research agronomists. And we are only one of the many firms that serve growers in the region. Our land grant universities provide us with vital research information which we can take directly to the farm. By cooperating and taking advantage of our combined resources whenever possible, we can be most effective in assisting Northwest farmers.

INDEPENDENT CROP CONSULTANTS

Farmers are increasingly using the services of independent crop consultants, who number about 3,500 nationally. Independent crop consultants are not associated with chemical suppliers, and many are specialists in integrated pest management and advise clients on nonchemical pest management strategies. Based on a national extension service survey of independent agricultural crop consultants, consultant-recommended practices most frequently used by clients are fertility management, crop rotation, planting pest-resistant varieties, and pest scouting. Of the total acreage of all crops under contract with consultants, corn acres account for about 32 percent, soybean acres for 19 percent, wheat acres for 13 percent, cotton acres for 17 percent, and rice acres for 2 percent. Thirty-seven percent of consultants indicated that universities are their primary source of information on nonchemical tactics. Information from other consultants was ranked most important by 23 percent of consultants. (The primary source of information for these other consultants was not reported.) The most valued means of obtaining information were seminars (first), workshops (second), and on-farm demos (third).

SOURCE: Natural Resources and Environment Division, Economic Research Service, US. Department of Agriculture, AERIE Updates: Crop Consultants, Number 3, 1995.

embodied with sellable commodities and products." Additionally, they find public extension is well situated to (a) provide information to public agencies, such as water quality control boards, about environmental conditions and the practices of farmers; (b) assist governments in establishing and enforcing environmental regulations, and (c) act as a liaison between farmers and confirmers on environmental issues.

In serving US. agriculture specifically, as well as US. society generally, an increasingly important role that public extension can and should playpen not likely to be taken on by the private sectors that of coordinating and bringing together diverse participants in and perspectives on the food and agricultural system. For example, extension can take an active role in bringing the needs and perspectives of consumers and other "nontraditional clientele" to the process of setting priorities at the college. In a consumer-driven system, it is especially important to draw the public into assessments of new food and agricultural technologies, such as genetically engineered varieties or growth promoters, to enhance the public's understanding of these technologies, and to assess their potential for widespread acceptance. In this sense, the committee believes that public extension in the future should be as much an integrator as it is a disseminator: an integrator of diverse players and perspectives in the food and fiber system.

Postlewait et al. (1993) argue that extension is also an ideal candidate to complement the efforts of university-based technology transfer offices to disseminate biotechnology innovations for agriculture. They argue that specialists can support technology transfer offices in preparing feasibility and profitability analyses and identifying potential clients. They can also work directly with university researchers to move innovations from the test tube to the field. As core members of interdisciplinary research teams, specialists can direct biotechnology research to specific agricultural problems and to the appropriate adaptation of innovations. Further, they can act as intermediaries between regulatory agencies and biotechnology practitioners.

Postlewaite et al. (1993) note that county-based farm advisors have important roles, too, in identifying farmers' needs for new products and leading local field tests to help identify the market potential of new biotechnology products. This latter effort may be particularly important for smaller biotechnology companies that are at a disadvantage in competition with large chemical and seed companies. The case these smaller companies can make for an active role on the part of cooperative extension, in coordination with technology transfer offices, rests on the heterogeneous nature of agricultural systems—thousands of plants, limited growing season for testing, and the need for site-specific adaptations—and the relative lack of a commercial network for dissemination and commercialization of agricultural biotechnology.

Serving Urban, Suburban, and Nonfarm Rural Clientele

U.S. extension may be unique in relation to other countries' agricultural extension services because of its relatively strong presence in nonfarm communities. U.S. extension began with a focus on farmers and farm families; but as people migrated from farms to rural towns and to cities, the services in these counties shifted. Where people went, so went extension's local funding base. The relocation of the farm population drew extension into rural towns to assist in household and family management. Success with traditional 4-H Clubs for farm and rural youth helped prepare extension for "youth at risk" and other leadership and citizenship programs in urban and suburban as well as rural areas. Extension's history of helping farm families meet their food needs and, in wartime, enhancing food production (through Victory Gardens) laid the basis for extension's successful urban gardening and Master Gardener programs. Extension is not necessarily the only or best agency to lead these nonfarm efforts, but its historical experiences and successes position it to have an important role.

Federal Mandates

Over the decades, amendments to Smith-Lever legislation broadened extension's mandate (National Research Council, 1995a). For example, a 1961 amendment authorized Smith-Lever funds to be used for resource and community development extension. Legislation in 1972 (the Federal Rural Development Act) authorized extension work in rural communities in agriculture and nonagricultural fields and funds for rural development and small-farm research and extension. Legislation in 1978 (the Resource Extension Act) authorized funding for extension programs in forestry and other renewable national resources. Additionally, since 1955 special extension programs with specific designations have been added and funded by Congress with supplementary funds in addition to Smith-Lever formula funds and formula funds for extension programs at 1890 colleges. Funds are allocated to these specified programs in three ways: (1) designated by Congress for specific institutions, (2) allocated using the Smith-Lever formula, and (3) allocated competitively. Federal funds for these specified extension programs currently total $128 million; about one-half of this amount is designated for the expanded food and nutrition education program (EFNEP) and about one-fifth is for "national extension priorities" in water quality, youth and family at risk, sustainable agriculture systems, and food safety and quality (National Association of State Universities and Land Grant Colleges, 1995).

Although this allocation differs significantly from state to state, today more than one-half of the time of extension staff, nationally, is devoted to programs that are applicable in both rural and urban areas. Included are programs focused on community, youth, family, and leadership development; other social and economic issues; and nutrition, diet, and health education (National Research Council, 1995a). In spite of the fact that many of these critical issues, such as nutrition, are vital to people regardless of where they live, there are those who argue that extension should concentrate on farm production and rural problems (Terry, 1995).

Program Evolution

As extension programs evolved in response to local needs and congressional mandates, the focus began to diverge from that of the research programs of the colleges of agriculture. Extension—particularly through the work of the county agents—puts more emphasis on human nutrition, diet, and health and on social and behavioral science issues, such as economic, community, and human development, than do the research programs of most colleges of agriculture. Most of those programs continue to be more focused on plant and animal sciences and natural resource management issues (National Research Council, 1995a).

The diversification of extension's programs does credit to its responsiveness to community needs but has not come without problems. Some of these have already been alluded to in this chapter and in Chapter 2. First, as extension resources have become more diffused, there has been considerable debate and confusion regarding extension's mission and mandate (see, for example, Terry, 1995). Second, extension's nonfarm (or, more accurately, nonproduction) programs appear to be less well linked to the research programs of the college of agriculture, which is often still extension's administrative home. Third, the role of USDA as the primary federal partner in these cooperative extension programs may be in question, as well as the linkages of these programs to related federal efforts. An additional issue, from the standpoint of analyzing the outcomes and effectiveness of these programs, is that their benefits are not readily measured as contributions to economic output or productivity (see Recommendation 13).

The committee believes that extension's programs must be broadly relevant to the U.S. public, not just the farm clientele. In fact, its future, as the farm population shrinks, depends on consumer support. The important issue to resolve is not whether extension serves farm or nonfarm clientele; the key issue is whether publicly financed extension programs provide public goods in the national interest. Such goods include enhanced human health and safety, economic opportunity, environmental quality, and sound information for public and private decision making on important public policy issues related to the food and agricultural system. There are nonfarm extension programs that meet these criteria as well as nonfarm extension programs that should be provided by the private sector or privately financed by users. (For example, garden advice tailored to the questions of an individual suburban gardener should probably be paid for by the gardener, unless local communities have specifically dedicated their tax dollars to agents that provide such individualized advice.) However, youth and family-at-risk programs may promote the national interest in reducing crime, drug abuse, and teen pregnancy and in strengthening families and, thus, warrant federal support.

The Research Link

With respect to the link to science, of particular concern to the committee is the need to connect researchers, extension specialists, and county agents in the fields of human nutrition, rural development, and social services. The connection between nutrition education programs and research has been recognized in the past as relatively weak for a number of reasons, including

- the relatively small share of experiment station research devoted to human nutrition;
- the lower ratio of university-based nutrition specialists to county agents with nutrition education responsibilities (in relation to the ratio of university-based agricultural specialists to county agents); and
- the lack of integration in the field of human nutrition itself (that is, among the disciplines of food science, human nutrition, and home economics) (Feller et al., 1984).

There are also many different university locations for nutritional science research. As

noted in *Opportunities in the Nutrition and Food Sciences* (National Research Council, 1994b),

> The land grant colleges and universities (with their focus on agriculture, rural communities, and the needs of consumers) have been largely responsible for the growth of the nutrition and food sciences in the United States. Much of the research in these disciplines has been conducted in departments of animal science, food science, and nutrition in schools of agriculture and home economics. Increasingly, research on diet's role in chronic disease is conducted by scientists in medical schools and schools of public health. Fundamental nutrition research is now conducted as well in more general university and professional school departments.

Extension, to be effective and scientifically sound, must be able to access all of these nutritional and food sciences locations. Additionally, although the challenge is substantial, extension specialists in human nutrition could have an important role in promoting needed interdisciplinary efforts among the food and nutrition-related disciplines.

Rural Economics

In the area of rural economic development, there is much work for extension to do. As documented in the *Profile* report (National Research Council, 1995a), off-farm income is the dominant income source for farm-operator households. Only 18 percent of farm-operator households received more on-farm income than off-farm income in 1991 (Gale and Harrington, 1993). The point is, today the rural economy underpins farming and its future opportunities as much or more than farming underpins the rural economy. Thus, the interests of the majority of farmers and of many rural communities remain closely intertwined.

The infrastructure needs of rural economies deserve a great deal of emphasis, including rural housing, communication systems, water and waste management, and access to health and educational facilities (Zuiches, 1994). Building the infrastructure is especially key to attracting and retaining private businesses and investment.

Human capital development is an especially important infrastructural need of rural areas, which extension can help fulfill. Rural areas are often human capital weak; they need well-educated individuals with leadership skills and the willingness to take on responsibilities in public posts often with very low pay. Information about and analyses of rural community tax policies and other public policies deserve emphasis by extension programs, too. Having access to such information and analyses improves the ability of rural policy makers and voters to make informed decisions about policy directions and changes that can enhance economic performance. It can also enhance the information base for private businesses considering locating in rural areas.

Despite these prominent needs in many rural areas, and their importance to the viability of a large number of U.S. farms, relatively few experiment station resources are devoted to social sciences generally or to rural sociology and rural economic development in particular. Additionally, the social sciences and their important contributions have not been emphasized by the competitive grants program for food and agricultural sciences, the USDA's National Research Initiative or, indeed, other federal research grants programs.

Conclusions

The committee concludes extension has an important current and future role, although not necessarily the lead role, in serving urban and suburban clientele and nonfarm rural communities. These nonfarm programs and services respond to national needs and have the potential to strengthen the rural economic and social infrastructure that is so important to farm and ranch families at the same time that they broaden the base

MULTIDISCIPLINARY FOUNDATION OF FOOD AND NUTRITIONAL SCIENCE

Although the work of food scientists has expanded and improved our food supply, many new challenges remain. Collaboration among engineers, microbiologists, molecular biologists, food scientists, and nutritionists is needed to create foods that are nutritious, palatable, and safe. Thus, nutritionists and food scientists must engage in interdisciplinary efforts with each other and with basic biological and social scientists.

Research in the biological sciences shows that some nutrients play key roles in regulating metabolism. Future efforts to identify nutrient-gene interactions will require the attention of nutritionists well trained in molecular, cellular, and integrative biology. Clinical nutritionists have demonstrated the role of diet in maintaining physiological function and preventing chronic disease, but future advances in understanding these relationships require joint efforts with physicians and biologists.

Designing successful public health and community intervention programs requires an understanding of human behavior, economics, epidemiology, anthropology, and political science. Interdisciplinary efforts among nutritionists and behavioral and social scientists are needed to meet this challenge. It is essential, therefore, that students in the nutrition and food sciences develop an understanding of the basic science of a related discipline such as molecular biology, microbiology, biochemistry, chemistry, engineering, medical science, sociology, or political science.

SOURCE: National Research Council. 1994b. Opportunities in the Nutrition and Food Sciences. Washington, D.C.: National Academy Press.

of public support for extension. The sense of the committee is that such programs could be strengthened, however, through a fuller utilization of the land grant university's resources in building the science base for nonfarm programs, stronger contributions from the social science disciplines, and synergies with related public service programs of other (non-USDA) federal agencies where there is much additional pertinent expertise. Strengthening these programs requires a commitment from the land grant university as a whole, as well as from the college of agriculture and its extension service. Such a commitment provides the university the opportunity to enhance its role in public service. The committee therefore offers the following set of three recommendations:

RECOMMENDATION 15. *Extension programs must be underpinned by an academic research base in the land grant university. Consequently, the committee strongly encourages land grant universities to embrace the mandate of outreach and extension and to ensure that the entire university is accessible and responsive as the research base for farm and nonfarm extension programs. To accomplish this, administrative structures, incentives, and reward recognition must be generated within the university to promote the commitment and involvement of faculty, staff, and administrators across the university to actively participate in outreach, extension, and public service.*

RECOMMENDATION 16. *Federal agencies (operating under the auspices of a Cabinet-level task force) should identify appropriate opportunities to link programs at the Health and Human Services, Commerce, and other departments to USDA-based extension, especially in the delivery of services to nonfarm clientele.*

RECOMMENDATION 17. *The research base for extension's nonfarm programs, such as community and economic development, human development, and public policy, should be enhanced by strengthening the land grant universities' applied research capacity in economics, sociology, public health, and related disciplines and their applications to extension programs.*

Financing Public Extension

Extension has considerable opportunity to take advantage of incentives and ability to exact payment for specific extension services. Doing so allows broadly derived public funds, such as those raised from general tax revenues, to be targeted toward programs with broad benefits. User fees should increasingly support extension services that provide primarily private benefits to individual producers or other users. Private benefits include such services as providing building plans, feeding rations, soil testing, pest scouting, and disease diagnostics; individualized advice for home gardeners; and individualized advice on tax and investment strategies. Providing such services for a fee has the potential to sharpen the clientele orientation of extension providers and the standards for service because failure to be competitive in providing quality services will result in a lack of business.

On the other hand there are foreseeable problems with providing fee-based services. The committee believes the great strength of the U.S. cooperative extension service has been its historical link to university research. In pursuing commercial opportunities, one problem is that extension advisors may reorient toward the marketplace and away from the university base. Thus, the committee believes the most important focus of public extension must be on those problems that lack incentives for private support but have the potential to enhance the provision of public goods. An additional problem is that there will be limited-resource producers who simply cannot pay and yet would derive great benefits from extension's services. Options to consider in order to guarantee services to low-income clientele include:

- means testing to determine eligibility for free public services;
- designating certain counties, where limited-resource farmers are a significant portion of the population, as free-service counties; and
- providing vouchers to qualifying limited-resource farmers.

RECOMMENDATION 18. *New and innovative approaches to augment extension financing should be pursued, as appropriate, taking into account implications for access to extension by limited-resource farmers and other limited-resource clientele groups.*

ALLOCATION FEDERAL EXTENSION FUNDS

One of the most important roles for the federal partner is to fund programs that deserve public support but that would be underfunded by states because the benefits are broadly shared across state lines. Additionally, federal support may be crucial to the success of a program with primarily local or state benefits that has the potential to become a national model for other state extension efforts. Urban youth programs, which have their roots in rural youth programs and a massive commitment of volunteers, may be particularly worthy of federal support and recognition on these grounds. Extension's youth programs offer a vehicle for bringing together rural and urban residents, encompassing a diversity of cultural backgrounds, and instilling the citizenship and technical skills that help pave the way into adulthood during difficult and challenging times for young people.

The federal government now supports cooperative extension through base funding (Smith-Lever funds and base funding for the 1890 colleges) and specified programs. Smith-Lever funds total $273 million; they are allocated to states by formula, most of which is based on a state's share of U.S. farm and rural population. The argument for the formula approach to funding extension activities is that it provides a stable funding base allowing extension experts to respond on a continuing basis to critical national, state, and local issues as and where such needs arise. Additionally, peculiar to the land grant colleges of agriculture, formula funding permitted the evolution of a system in which the individual time and effort of many faculty are split among some combination of research, extension, and teaching. Those faculty whose research appointment is supported by formula funds and who also have extension (or teaching) appointments are well positioned to link their research with ongoing extension (or teaching) activities.

Arguments against formula funding include the lack of effective means to determine accountability, in terms of how the funds are used, and the lack of peer review of the programs and their methodologies, which would provide incentives to update program content, priorities, and delivery techniques. There is a special need in today's environment—characterized by high public demand for accountability, a rapidly changing knowledge base, and rapidly evolving opportunities for delivery mechanisms—for the incentives and rewards associated with competitive funding of extension programs. Additionally, using rural and farm population as a base for allocating federal dollars fails to capture the broadened applicability of cooperative extension programs to urban and suburban clientele or the broader consumer constituency for agricultural and food systems knowledge, know-how, and performance. The committee therefore makes the following pair of recommendations:

RECOMMENDATION 19. *A new formula by which base food and agricultural extension funds are allocated within the land grant system should be designed and implemented to accurately reflect the full range of food and agricultural extension service beneficiaries.*

RECOMMENDATION 20. *All national extension initiatives should be available on a competitive basis to land grant and non-land grant institutions. Consistent with the committee's prior recommendations (Recommendations 3, 4, 15, and 17), these competitive grants should provide incentives for*

- *multistate, multi-institution, or regional extension programs;*
- *new and innovative approaches to the delivery of extension services, particularly where access can be expanded significantly and benefits shared across political boundaries;*
- *programs that significantly improve the science base for extension programs, such as those dealing with human nutrition education and social science issues; and*
- *programs that enhance the public service component of academic programs.*

SUMMARY AND CONCLUSIONS

Extension is likely to evolve differently around the country. In fact it must do so if it is to continue to be responsive to local and state agricultural and community needs, which vary from locality to locality. Extension in California, the nation's most populous and also most agricultural state, does not and will not resemble extension in West Virginia, one of the nation's most rural but least agricultural states. In California, extension is focused on agricultural production and natural resource management and the dissemination and adoption of less-chemical intensive pest management strategies. In West Virginia, extension is much more heavily focused on community resource and economic development, family development, and youth development (National Research Council, 1995a).

Differing university contexts and needs will also drive the future of extension at the state level. For example, where universities are heavily committed to basic research,

extension will increasingly engage in integrative and adaptive research. In other university environments, extension may specialize in technical advice for a fee or the coordination and facilitation of community activities around food and agricultural issues. Despite these differences, the following important attributes must distinguish the nationwide extension system of tomorrow. It will have to be

- results driven,
- relevant to consumers and producers,
- science based, and
- more efficient in both delivery mechanisms and the use of public funds.

References

Adusei, E. O., and G. W. Norton. 1990. The magnitude of agricultural maintenance research in the USA. J. Prod. Agric. 3:1-6

Allen, C. E. 1992. Breaking traditions in curriculum design. Pp. 188-198 in Agriculture and the Undergraduate. Washington, D.C.: National Academy Press.

Alston, J. M., and P. G. Pardey. 1995. Agricultural Science Policy. University of California, Davis, California and International Food Policy Research Institute, Washington, D.C. Photocopy.

Alston, J. M., and P. G. Pardey. 1996. Making Science Pay: The Economics of Agricultural R&D Policy. Washington, D.C.: American Enterprise Institute.

American Diabetes Association. 1993. Diabetes: 1993 Vital Statistics.

Anderson, M. D. 1995. The life cycle of alternative agricultural research. Am. J. Alt. Agric. 10:3-9.

Ballenger, N., and D. Kouadio. 1995. The National Research Council study of the colleges of agriculture at land grant universities. Am. J. Agric. Econ. 77:243-250.

Beattie, B. 1991. Some almost-ideal remedies for healing land grant universities. Am. J. Agric. Econ. 73:1307-1321.

Beus, C. E., and R. E. Dunlap. 1992. The alternative-conventional agriculture debate: Where do agricultural faculty stand? Rural Sociol. 57:363-380.

Blakeslee, L. 1987. Measuring the requirements and benefits of productivity maintenance research. Pp. 67-83 in Evaluating Agricultural Research and Productivity. Miscellaneous Publication 52-1987. St. Paul: Minnesota Agricultural Experiment Station, University of Minnesota.

Boyer, E. 1990. Scholarship Reconsidered: A Special Report. The Carnegie Foundation for the Advancement of Teaching. Lawrenceville, N.J.: Princeton University Press.

Bradshaw, D. E., and D. Marquart. 1990. America Needs Doctors of Plant Health: A Proposal to Establish and Educate a New Profession. Photocopy.

Busch, L., and W. B. Lacy. 1983. Science, Agriculture, and the Politics of Research. Boulder, Colo.: Westview Press.

Byerly, R., Jr., and R. A. Pielke, Jr. 1995. The changing ecology of United States science. Science 269:1531-1532.

Campbell, J. R. 1995. Reclaiming a Lost Heritage: Land Grant and Other Higher Education Initiatives for the Twenty-first Century. Ames: Iowa State University Press.

Cary, J. W. 1993. Changing foundations for government support of agricultural extension in economically developed countries. Sociologia Ruralis 33:334-345.

Castle, E. 1981. Agricultural Education and Research: Academic Crown Jewel or Country Cousin? Washington, D.C.: Resources for the Future.

Christy, R. D., and L. Williamson, eds. 1992. A Century of Service: Land Grant-Colleges and Their Universities, 1890-1990. New Brunswick, N.J.: Transaction Publishers.

Chubin, D. E., and E. J. Hackett. 1990. Peerless Science: Peer Review and U.S. Science Policy. Albany:State University of New York Press.
Cochrane, W. W.1979. The Development of American Agriculture: An Historical Analysis. Minneapolis:University of Minnesota Press.
Corson, D. R.1995. Multidisciplinary programs in universities. Pp. 277-286 in Reinventing the Research University, C. K. N. Patel, ed. Los Angeles: Regents of the University of California.
Council on Food, Agricultural, and Resource Economics. 1994. Industrialization of U.S. Agriculture: Policy, Research, and Education Needs. Photocopy.
Daquel, L. T., and D. C. Dahmann. 1993. Residents of Farms and Rural Areas: 1991, U.S. Bureau of the Census, Current Population Reports Series P20, No. 472. Washington, D.C.: U.S. Government Printing Office.
Debertin, D. 1993. Building consumer support for agricultural research and educational programs. Choices (4th quarter):34-35.
Dillman, D. A., J. A. Christenson, P. Salant, and P. W. Warner. 1995. What the Public Wants from Higher Education: work force Implications from a 1995 National Survey. Technical Report #95-52. Pullman, Wash.: Social and Economic Sciences Research Center, Washington State University.
Doyle, J. 1985. Altered Harvest: Agriculture, Genetics, and the Fate of the World Food Supply. New York: Viking Penguin.
Dunbar, R. 1995. The Trouble with Science. London: Faber.
Educational Testing Service. 1995. GRE 1995-96 Guide to the Use of the Graduate Record Examination Program. Princeton, N.J.: Educational Testing Service.
Evenson, R. E. 1979. A century of agricultural research and productivity change research, invention, extension and productivity change in U.S. agriculture: An historical decomposition analysis. Pp. 146-228 in Research and Extension Productivity in Agriculture, A. Araji, ed. Moscow: Department of Agricultural Economics, University of Idaho.
Executive Office of the President. 1995. Economic Report of the President 1995. Washington, D.C.: Government Printing Office.
Feller, I., L. Kaltreider, P. Madden, D. Moore, and L. Sims. 1984. The Agricultural Technology Delivery System. Philadelphia: Institute for Policy Research and Evaluation, The Pennsylvania State University.
Feller, I., P. Madden, L. Kaltreider, D. Moore, and L. Sims. 1987. The new agricultural research and technology transfer policy agenda. Res. Policy 16:315-325.
Frazo, E. 1995. The American Diet: Health and Economic Consequences. Agriculture Information Bulletin No. 711. Washington, D.C.: U.S. Department of Agriculture, Economic Research Service.
Fuglie, K., N. Ballenger, K. Day, C. Klotz, M. Ollinger, J. Reilly, U. Vasavada, and J. Yee. 1996. Agricultural Research and Development: Public and Private Investments Under Alternative Markets and Institutions. Agricultural Economics Report. Washington, D.C.: U.S. Department of Agriculture, Economic Research Service.
Gale, H. F., and D. H. Harrington. 1993. U.S. Farms: Diversity and Change. Agricultural Outlook 198:3-6. Washington, D.C.: U.S. Department of Agriculture, Economic Research Service.
Godfrey, D., and A. Franklin. 1992. Extension programs at the 1890 land grant institutions. Pp. 59-68 in A Century of Service, R. D. Christy and L. Williams, eds. New Brunswick, N.J.: Transaction Publishers.
Goeker, A. D., K. J. Coulter, and M. Stanton. 1995. Employment Opportunities for College Graduates in the Food and Agricultural Sciences: 1995-2000. West Lafayette, Ind.: Purdue University.
Good, M., and N. Lane. 1994. Producing the finest scientists and engineers for the 21st century. Science 266:742.
Goodman, R. M. 1992. The challenges for professional education in agriculture: a corporate vantage point. Pp. 41-50 in Agriculture and the Undergraduate. Washington, D.C.: National Academy Press.
Gordon, J. C. 1992. The environmental curriculum: An undergraduate land grant future? Pp. 51-54 in Agriculture and the Undergraduate. Washington, D.C.: National Academy Press.
Greenwood, M. R. C. 1995. Societal expectations from research universities and the higher education system. Pp. 31-43 in Reinventing the Research University, C. K. N. Patel, ed. Los Angeles: Regents of the University of California.
Groen, J., E. Smit, and J. Eijsvoogel, eds. 1990. The Discipline of Curiosity: Science in the World. New York: Elsevier Science.
Hadwiger, D. F. 1982. The Politics of Agricultural Research. Lincoln: University of Nebraska Press.
Handelsman, J. 1992. Changing the image of agriculture through curriculum innovation. Pp. 199-203 in Agriculture and the Undergraduate. Washington, D.C.: National Academy Press.

Hassebrook, C., and G. Hegyes. 1989. Choices for the Heartland: Alternative Directions in Biotechnology and Implications for Family Farming, Rural Communities, and the Environment. Ames: Iowa State University.

Hayami, Y., and V. W. Ruttan. 1985. Agricultural Development: An International Perspective. Baltimore: Johns Hopkins University Press.

Hildreth, R. J., and W. Armbruster. 1981. Extension program delivery—past, present, and future: An overview. Am. J. Agric. Econ. 63:853-858.

Howell, J. 1985. Recurrent Costs and Agricultural Development. London: Overseas Development Institute.

Huffman, W. E. 1976. The productive value of human time in U.S. agriculture. Am. J. Agric. Econ. 58:961-974.

Huffman, W. E., and J. A. Miranowski. 1981. An economic analysis of expenditures on agricultural experiment station research. Am. J. Agric. Econ. 63:104-118;(February):744-759.

Huffman, W. E., and R. E. Evenson. 1993. Science for Agriculture: A Long-Term Perspective. Ames: Iowa State University Press.

Johnston, W. B., and A. H. Packer. 1987. work force 2000: Work and Workers for the 21st Century. Indianapolis, Ind.: Hudson Institute.

Joint Council on Food and Agricultural Sciences. 1995. Accomplishments for Research, Extension, and Higher Education: A Report to the Secretary of Agriculture and the U.S. Congress. Washington, D.C.: U.S. Department of Agriculture.

Just, R. E., and W. E. Huffman. 1992. Economics principles and incentives: Structure, management, and funding of agricultural research in the United States. Am. J. Agric. Econ. 74:1101-1108.

Kalaitzandonakes, N. G., and B. Bulloch. 1996. Technology and information transfer in U.S. agriculture. In Privatization of Technology and Information Transfer in U.S. Agriculture: Research and Policy Implications, Steven Wolf, ed. Albany, Iowa: St. Lucie Press and the Soil and Water Conservation Society.

Klotz, C., K. Fuglie, and C. Pray. 1995. Private Sector Agricultural Research Expenditures in the United States, 1960-92. Staff Paper No. 9525. Washington, D.C.: U.S. Department of Agriculture, Economic Research Service.

Kunkel, H. O., and P. Thompson. 1996. Thinking through higher education in agriculture: content, values, and purpose. Pp. 17-40 in Revolutionizing Higher Education in Agriculture: Framework for Change, H. O. Kunkel, I. L. Maw, and C. L. Skaggs, eds. Ames, Iowa: Robson and Associates.

Kunkel, H. O., I. L. Maw, and C. L. Skaggs, eds. 1996. Revolutionizing Higher Education in Agriculture: Framework for Change. Ames, Iowa: Robson and Associates.

Lacy, W. B. 1993. Can agricultural colleges meet the needs of sustainable agriculture? Am. J. Alt. Agric. 8:40-45.

LeBlanc, C. 1996. The White House Initiative on Historically Black Colleges and Universities. Paper presented to the staff of the National Research Council, February 22, 1996, Washington, D.C.

Le Gouis, M. 1991. Alternative financing of agricultural extension: Recent trends and implications for the future. In Agricultural Extension: Worldwide Institutional Evolution and Forces for Change, W. M. Rivera and D. J. Gustafson, eds. Amsterdam: Elsevier.

Lipman-Blumen, J. 1987. Priority setting in agricultural research. Pp. 139-173 in Policy for Agricultural Research, V. W. Ruttan and C. E. Pray, eds. Boulder, Colo.: Westview Press.

Lockeretz, W., and M. D. Anderson. 1993. Agricultural Research Alternatives. Lincoln: University of Nebraska Press.

Madden, J. P. 1986. Toward a new covenant for agricultural academe. Pp. 267-279 in The Agricultural Scientific Enterprise, L. Busch and W. B. Lacy, eds. Boulder, Colo.: Westview Press.

Malone, T. F. 1994. Sustainable Human Development: A Paradigm for the 21st Century. White paper for the National Association of State Universities and Land Grant Colleges. Research Triangle Park, N.C.: Sigma Xi Center.

Marston, E. 1993. Piece by piece we're losing the land. High Country News, July 26.

Mastron, B. 1995. A dose of the real world: Students gain hands-on experience in class. Impact (University of Florida, Institute of Food and Agricultural Sciences) (summer):7-9.

Mayer, A., and J. Mayer. 1974. Agriculture, the island empire. Daedalus (summer):83-95.

Mayes, M. 1992. Status of agricultural research programs at 1890 land grant institutions and Tuskegee University. Pp. 53-58 in A Century of Service, R. D. Christy and L. Williams, eds. New Brunswick, N.J.: Transaction Publishers.

Meyer, J. H. 1968. A Vision for A & ES. University of California, Davis. Photocopy.

Meyer, J. H. 1993. The stalemate in food and agricultural research, teaching, and extension. Science 260:1006-1007.

Meyer, J. H. 1995. Transforming the Land Grant College of Agriculture for the Twenty-First Century. Davis: University of California.

Napit, K. B., G. W. Norton, R. F. Kazmierczak, Jr., and E. G. Rajotte. 1988. Economic impacts of Extension integrated pest management programs in several states. J. Econ. Entomol. 81:251-256.

National Academy of Sciences. 1995. Allocating Federal Funds for Science and Technology. Washington, D.C.: National Academy Press.

National Agricultural Research and Extension Users Advisory Board. 1995. Sciene and Education 2000. Washington, D.C.: U.S. Government Printing Office.

National Association of State Universities and Land Grant Colleges. 1995. The Unique Land Grant System Working for People, Food, Agriculture, Environment Through Teaching, Research, and Extension. Budget Recommendations for FY1996. Washington, D.C.: National Association of State Universities and Land Grant Colleges.

National Institutes of Health. 1992. Orientation Handbook for Members of Scientific Review Groups. Public Health Service, U.S. Dept. of Health and Human Services. Washington, D.C.: U.S. Government Printing Office.

National Research Council. 1972. Report of the Committee on Research Advisory to the U.S. Department of Agriculture. Springfield, Va.: National Technical Information Service.

National Research Council. 1987. Agricultural Biotechnology: Strategies for National Competitiveness. Washington, D.C.: National Academy Press.

National Research Council. 1989a. Alternative Agriculture. Washington, D.C.: National Academy Press.

National Research Council. 1989b. Investing in Research: A Proposal to Strengthen the Agricultural, Food, and Environmental System. Washington, D.C.: National Academy Press.

National Research Council. 1989c. A Common Destiny: Blacks and American Society. Washington, D.C.: National Academy Press.

National Research Council. 1992. Agriculture and the Undergraduate. Washington, D.C.: National Academy Press.

National Research Council. 1993. Soil and Water Quality: An Agenda for Agriculture. Washington, D.C.: National Academy Press.

National Research Council. 1994a. Investing in the National Research Initiative. Washington, D.C.: National Academy Press.

National Research Council. 1994b. Opportunities in the Nutrition and Food Sciences. Washington, D.C.: National Academy Press.

National Research Council. 1995a. Colleges of Agriculture at the Land Grant Universities: A Profile. Washington, D.C.: National Academy Press.

National Research Council. 1995b. Reshaping the Graduate Education of Scientists and Engineers. Washington, D.C.: National Academy Press.

National Research Council. 1995c. Research-Doctorate Programs in the United States: continuity and Change. Washington, D.C.: National Academy Press.

National Research Council. 1996. Ecologically Based Pest Management: New Solutions for a New Century. Washington, D.C.: National Academy Press.

National Science Foundation. 1986. National Science Foundation Advisory Committee on Merit Review. Final Report. NJF86-93. Washington, D.C.: National Science Foundation.

O'Brien, P. 1994. Implications for public policy. Pp. 296-318 in Food and Agricultural Markets: The Quiet Revolution, L. P. Schertz and L. M. Daft, eds. Washington, D.C.: The National Planning Association and the U.S. Department of Agriculture.

Office of Science and Technology Policy. 1991. By the Year 2000: First in the World. Report of the FCCSET Committee on Education and Human Resources. Washington, D.C.: Office of Science and Technology Policy.

Office of Technology Assessment, U.S. Congress. 1995. Challengesfor U.S. Agricultural Research Policy . OTA-ENV-639. Washington, D.C.: U.S. Government Printing Office.

Office of Technology Assessment, U.S. Congress. 1992. A New Technological Era for American Agriculture. OTA-F-474. Washington, D.C.: U.S. Government Printing Office.

Paarlberg, D. 1995. Understanding the changing structure of American agriculture. Purdue University. Photocopy.

Pingali, P. 1994. Technological prospects for reversing the declining trend in Asia's rice productivity. Pp. 384-401 in Agricultural Technology: Policy Issues for the International Community, J. R. Anderson, ed. Wallingford, Oxfordshire, U.K.: CAB International.

Pinstrup-Anderson, P., and R. Pandya-Lorch. 1994. Alleviating Poverty, Intensifying Agriculture, and Effectively Managing Natural Resources. Food, Agriculture and the Environment Discussion Paper 1. Washington, D.C.: International Food Policy Research Institute.

Postlewait, A., D. Parker, and D. Zilberman. 1993. The advent of biotechnology and technology transfer in agriculture. Technol. Forecasting Social Change 43:271-287.

Povlacs Lunde, J., M. Baker, F. H. Buelow, L. Schultz Hayes. 1996. Reshaping Curricula: Revitalization Programs at Three Land Grant Universities. Boston, Mass.: Anker Publishing.

Powers, M. 1995. Land grant universities face the future. Cornell Focus 4:23-27.
Rasmussen, W. D. 1989. Taking the University to the People: Seventy-five Years of Cooperative Extension. Ames: Iowa State University Press.
Reichelderfer, K. 1991. What does society want? Pp. 11-21 in Agriculture's Contract with Society: A Proceedings of the ASAE Roundtable Series. St. Joseph, Mich.: American Society of Agricultural Engineers.
Ritchie, I. 1995. From the public to the private sector: The Agriculture New Zealand story. Photocopy.
Roberts, E., and K. R. Smith, eds. 1995. Learning from the Grassroots: Input for Federal Food and Agricultural Research and Extension Programs. College Park, Md.: Charles Valentine Riley Memorial Foundation.
Rockefeller Foundation and Office of Science and Technology Policy. 1982. Science for Agriculture: Report of a Workshop on Critical Issues in American Agricultural Research. New York: The Rockefeller Foundation.
Rosegrant, M. W., M. Agcaoili-Sombilla, and N. Perez. 1995. Global Food Projections to 2020: Implications for Investment. Washington, D.C.: International Food Policy Research Institute.
Ruttan, V. W. 1971. Technology and the environment. Am. J. Agric. Econ. 53:707-717.
Samuelson, P. A. 1954. The pure theory of public expenditure. Rev.Econ. Stat. 36:387-89.
Sanderson, D., ed. 1992. Shared Vision: An Implementation Plan for the New England Cooperative Extension Consortium. Report of the Directors of the Cooperative Extension Organizations of the New England Land Grant Universities. Ellsworth, Maine: The Borealis Press, Inc.
Schuh, G. E. 1986. Revitalizing land grant universities. Choices (2nd quarter):6-10.
Smith, Katherine Reichelderfer. Making Alternative Agriculture Research Policy. American Journal of Alternative Agriculture. Vol. 10, number 1, 1995, pp. 10-18.
Stern, J. D., ed. 1994. The Condition of Education in Rural Schools. Washington, D.C.: U.S. Department of Education, Office of Educational Research and Improvement.
Strange, M. 1982. The Path Not Taken. Walthill, Nebr.: Center for Rural Affairs.
Terry, L. 1995. Cooperative Extension's urban expansion: The default of leadership or a responsiveness to changing times. Admin. Soc. 27:54-81.
Townsend, C., and H. O. Kunkel. 1996. Curriculum design. Pps. 62-73 in Revolutionizing Higher Education in Agriculture: Framework for Change, H. O. Kunkel, I. L. Maw, and C. L. Skaggs, eds. Ames, Iowa: Robson and Associates.
University of California. 1993. Academic Plan. College of Agricultural and Environmental Sciences. University of California, Davis, California.
United Nations. 1995. World Population Prospects: 1994 Revision. New York: United Nations.
U.S. Congress, Office of Technology Assessment. 1995. Targeting Environmental Priorities in Agriculture: Reforming Program Strategies. OTA-ENV-640. Washington, D.C.: Government Printing Office.
U.S. Department of Agriculture. 1995. Inventory of Agricultural Research, Fiscal Year 1994. Washington, D.C.: Government Printing Office.
U.S. Department of Agriculture, Economic Research Service. 1996. Characteristics and Risk Management Needs of Limited Resource and Socially Disadvantaged Farmers. A Report to the Federal Crop Insurance Corporation Office of Risk Management, Farm Service Agency. Washington, D.C.: Government Printing Office.
U.S. Department of Agriculture, Economic Research Service. 1994. Rural poverty rate remains higher than urban rate. Rural Conditions and Trends 5:12.
U.S. Department of Agriculture, Natural Resources and Environment Division, Economic Research Service. 1995. AREI Updates: Crop Consultants. Number 3. Washington, D.C.: Natural Resources and Environment Division, Economic Research Service, U.S. Department of Agriculture.
U.S. Department of Education. 1993. Digest of Education Statistics 1993. Washington, D.C.: U.S. Department of Education.
U.S. Department of Education. 1995. The Condition of Education 1995. Washington, D.C.: U.S. Department of Education, National Center for Education Statistics.
U.S. General Accounting Office. 1988. Food Stamps: Reasons for Nonparticipation. GAO/PEMD-89-SBR. Washington, D.C.: Government Printing Office.
Vietor, D. M., and L. D. Moore. 1992. Teaching agricultural science as a system. Pp. 222-236 in Agriculture and the Undergraduate, National Research Council. Washington, D.C.: National Academy Press.
Warner, P. D., and J. A. Christenson. 1984. The Cooperative Extension Service: A National Assessment. Boulder, Colo.: Westview Press.
Weiser, C. J. 1996. The Value System of a University—Rethinking Scholarship. Oregon State University, Corvallis, Oregon. Photocopy.
W. K. Kellogg Foundation. (undated). Food Systems Professions Education Initiative.

Wolf, S. 1995. Cropping systems and conservation policy: The roles of agrichemical dealers and independent crop consultants. J. Soil Water Conserv. 50:263-270.

Wolf, S., ed. 1996. Privatization of Technology and Information Transfer in U.S. Agriculture: Research and Policy Implications. Del Ray Beach, Fla.: St. Lucie Press and the Soil and Water Conservation Society.

Yee, J. 1992. Assessing rates of return to public and private agricultural research. J. Agric. Econ. Res. 44:35-41.

Zilberman, D., D. Sunding, and M. Khanna. 1996. The changing nature of agricultural markets: Implications for privatization of technology, information transfer and the role of land grant research and extension. In Privatization of Technology and Information Transfer in U.S. Agriculture: Research and Policy Implications, Steven Wolf, ed. Albany, Iowa: St. Lucie Press and the Soil and Water Conservation Society.

Zuiches, J. 1994. Reinventing rural sociology: Processes and substance. Rural Sociol. 59:197-215.

About The Authors

Anthony S. Earl (*chair*) has been a partner in the law firm of Quarles & Brady, Madison, Wisconsin, since 1987. Prior to that he had been governor of Wisconsin (1983–1986). Earl received his J.D. degree from the University of Chicago in 1961. An advocate of environmental and civic responsibility, as governor, he successfully advanced through the legislature a significant number of initiatives in the areas of education, equal opportunity, economic development, and protection of the environment. Earl also served as secretary of the departments of natural resources and of administration for the state of Wisconsin and is a co-founder of the Center for Clean Air Policy and a board member of the Great Lakes Protection Fund, Common Cause, Resources for the Future, and other environmental and civic organizations.

R. Lee Baldwin, affiliated with the University of California since 1963, is Sesnon Professor of Animal Science at the University of California, Davis. He has been the recipient of both Guggenheim and Fulbright fellowships. Baldwin earned his M.S. degree in dairy nutrition and Ph.D. degree in biochemistry and nutrition from Michigan State University. His primary areas of research interest include modeling ruminant digestion and animal metabolism, nutritional energetics, and the physiology of lactation. Baldwin was elected to the National Academy of Sciences in 1993.

John C. Gordon is Pinchot Professor and the acting director of the Yale Institute of Biospheric Studies at Yale University. He received his B.S. degree and his Ph.D. degree in plant physiology from Iowa State University. Gordon's primary areas of expertise are plant physiology and silviculture, and his research includes work in tree physiology and ecology, especially biological nitrogen fixation. A member of the Society of American Foresters as well as other organizations, he is actively working to develop research methodologies and science and policy interactions.

Gordon E. Guyer, director of the Michigan Department of Agriculture, originally retired from Michigan State University (MSU) in 1986 after a distinguished 33-year career in agriculture education and natural resources development. In 1988 he was recruited to

return as professor emeritus and vice president for government affairs. In 1992 he was recruited to return as president of MSU, a position he held until 1993. Guyer was formerly the director of the Michigan Department of Natural Resources. His B.S., M.S., and Ph.D. degrees were earned in entomology at MSU. He has served as consultant to governments worldwide on agriculture and natural resource issues.

Fred Harrison, Jr., since 1982, has been administrator and director of the Cooperative Extension Program at the School of Agriculture, Home Economics, and Allied Programs, Fort Valley State College, Fort Valley, Georgia. He also serves on the executive committee of USDA's Joint Council on Food and Agricultural Sciences and has chaired the Extension Committee on Organization and Policy. Harrison earned his M.Ed. degree from the University of Georgia and his Ph.D. degree in agricultural education and administration from Ohio State University. His area of research is agricultural extension education and administration.

Edward A. Hiler is vice chancellor and dean of Agriculture and Life Sciences at Texas A&M University and director of the Texas Agricultural Experiment Station. Prior to that he was head of Texas A&M University's Department of Agricultural Engineering (1974–1988). Hiler earned his B.S., M.S., and Ph.D. degrees in agricultural engineering from Ohio State University. He serves as a consultant to the Office of Technology Assessment, the Office of Water Research and Technology, and several U.S. and western European universities regarding environmental quality and the future direction of agricultural engineering. He is a past-president of the American Society of Agricultural Engineers and in 1987 was elected to the National Academy of Engineering.

Marlyn L. Jorgensen is a partner in Jorg-Anna Farms and president and C.E.O. of Timberlane Hogs, Ltd., Garrison, Iowa. He is president of the Iowa Producers Co-Op and a board member of Sunrise Energy. He is also past-president and chair of the American Soybean Association, past-director of Iowa Farm Bureau Federation, and past-coordinator of Benton Rural Development Group. Jorgensen received his degree in animal science from Iowa State University. He is most actively involved in farming economics in relation to national economic indicators and government policy.

Daryl B. Lund became dean of the College of Agriculture and Life Sciences at Cornell University in August 1995. Prior to that, he was the executive dean and executive director of Cook College and of the New Jersey Experiment Station at Rutgers—The State University of New Jersey. After receiving his Ph.D. degree in food science and chemical engineering from the University of Wisconsin in 1968, Lund joined the Department of Food Science as a professor of food engineering. He served as chair of that department (1984–1987) until he moved to Rutgers as chair of the Food Science Department. His research expertise includes food process engineering with special emphasis on simultaneous heat and mass transfer, energy and food processing, and development of microwave-assisted heat and mass transfer operations.

Thomas F. Malone is a Distinguished University Scholar at North Carolina State University and director of the Sigma Xi Center, Research Triangle Park, North Carolina. Malone has held tenured faculty appointments at the Massachusetts Institute of Technology and the University of Connecticut where he was dean of the graduate school. He has served as president of the Meteorological Society, the American Geophysical Union, and of the Scientific Honor Society Sigma Xi. Elected to the National Academy of Sciences in 1968, Malone served as Foreign Secretary of the National Academy of Sciences from 1978 until 1982. His Sc.D. was earned from the Massachusetts Institute of Technology in 1946. Malone's primary area of research is sustainable human development.

Mortimer H. Neufville is acting vice president for academic affairs and, since 1983, has been dean of School of Agricultural Sciences and the 1890 research director at the University of Maryland, Eastern Shore. He is also the associate director of the Maryland Agricultural Experiment Station. Neufville's responsibilities include supervising thirteen academic departments and a comprehensive program encompassing many aspects of agriculture in domestic and international research and education programs in food and agricultural sciences. Neufville earned his M.S. and Ph.D. degrees in animal science from the University of Florida, Gainesville.

Elizabeth D. Owens is manager of government affairs for ISK Biosciences Corporation, Mentor, Ohio. In her present position, she is responsible for managing federal registration of ISK herbicides and fungicides. She oversees operation of the ISK Biosciences Corporation Washington, D.C., area office. Prior to joining ISK, Owens was manager, commercial development and regulatory affairs for BioTechnica International, Inc., Cambridge, Massachusetts. Owens has held research positions in industry and at the University of Massachusetts, both Boston and Amherst campuses. Owens received her training in food science, entomology and pest management. She earned her B.S. degree from the University of Idaho, M.S. degree from Iowa State University, and Ph.D. degree from the University of Massachusetts.

C. Alan Pettibone is superintendent of the Western Washington Research and Extension Centers (at Puyallup, Vancouver, Long Beach, and Mt. Vernon), Washington State University (WSU). When named to the committee, he was assistant director of Cooperative Extension for Agriculture and Natural Resources at WSU. Pettibone received his Ph.D. degree in Agricultural Engineering from Cornell University and has extensive experience in agriculture and natural resource issues from both a technical and policy viewpoint, having served in a number of administrative positions at WSU and as director of the Washington State Department of Agriculture for almost a decade.

Allen Rosenfeld is senior vice president for programs and acting co-director at Public Voice for Food and Health Policy, a Washington, D.C.-based consumer group. He has been responsible for Public Voice's legislative and regulatory work on food safety, food labeling, biotechnology, pesticide policy, and sustainable agriculture. Before joining Public Voice, Rosenfeld conducted field research in Guatemala on expansion of "nontraditional" exports and was an assistant professor in the Agricultural Management Department of the California Polytechnic State University (1982–1986) and, while there, also was coordinator of the International Agricultural Development Program. He received his Ph.D. degree in agricultural economics from Cornell University.

Charles F. Saul, prior to his retirement in 1995, was president, C.E.O., and general manager of Agway, Inc., Syracuse, New York, a food marketing cooperative owned by 91,000 farmer-stockholders. Saul joined Agway in 1954. Following military service, he returned to Agway and began his advance from district manager through vice president, to group vice president, executive vice president and chief operations officer, assistant general manager, and finally general manager and president. Having built a career in agribusiness management, Saul now serves on the boards of directors for several agribusiness corporations and advocacy organizations in New York state. Saul is a graduate of Cornell University.

G. Edward Schuh is dean of the Hubert H. Humphrey Institute of Public Affairs at the University of Minnesota, St. Paul. Prior to that he was director of Agriculture and Rural Development for the World Bank in Washington, D.C., (1984–1987) and head of the Department of Agricultural and Applied Economics, University of Minnesota (1979–1984). Schuh holds an M.S. degree from Michigan State University and M.A. and Ph.D.

degrees from the University of Chicago. His career has included serving in various academic capacities at Purdue University (1959–1979), as program advisor to the Ford Foundation in Brazil (1966–1972), as senior staff economist on President Ford's Council of Economic Advisers (1974–1975), and as USDA deputy undersecretary for International Affairs and Commodity Programs (1978–1979).

George E. Seidel, Jr., is professor of reproductive physiology at Colorado State University. He received his B.S. degree from The Pennsylvania State University and M.S. and Ph.D. degrees in reproductive physiology from Cornell University. He has served as a research fellow at Harvard Medical School; professor in the Department of Physiology, at Colorado State; was a visiting associate professor in the Biology Department at Yale University; and was visiting scientist at the Whitehead Institute. Seidel's research includes superovulation and embryo transfer, in vitro oocyte maturation and fertilization, cryopreservation of livestock embryos, and embryo microsurgery. Seidel was elected to the National Academy of Sciences in 1992.

Jo Ann Doke Smith is a founding partner of the consulting firm of Smith Associates, Texas and Florida, and has extensive experience in both public and private sectors of the agriculture industry. She has served as USDA's assistant secretary for Marketing and Inspection Services, president of the National Cattlemen's Association, and a member of the governor's Task Force on the Future of Florida Agriculture. Ms. Smith is an active member of the boards of directors of the Iowa Beef Producers, Inc., and Purina Mills, Inc., and is involved in agricultural marketing as it relates to government policy.

Katherine R. Smith is director of the Commercial Agriculture Division of USDA's Economic Research Service and formerly director of the Policy Studies Program at the Henry A. Wallace Institute for Alternative Agriculture, Greenbelt, Maryland. The interdisciplinary program she led assessed the implications of policy alternatives for the sustainability of agricultural systems. Smith earned her Ph.D. in agricultural and resource economics from the University of Maryland. Smith's principal areas of expertise are agricultural and resource policies and the relationship between agricultural production and environmental quality.

James B. Wyngaarden recently retired from a distinguished career that included holding the following positions: chair of the Department of Medicine at Duke University (1967–1982) and associate vice chancellor of Duke University, director of the National Institutes of Health (1982–1989), Foreign Secretary of the National Academy of Sciences and the Institute of Medicine (1990–1994), and, concurrently, director of the Human Genome Organization (1990–1994). Dr. Wyngaarden received his M.D. degree from the University of Michigan and was elected to the Institute of Medicine in 1973 and the National Academy of Sciences in 1974; he is a fellow of the Royal College of Physicians of London; and a member of the American Society of Clinical Investigators.

Elisabeth A. Zinser became chancellor of the University of Kentucky in July 1995 after having served as president of the University of Idaho. She was also the chair of the Committee on Outreach and Technology Transfer for the National Association of State University Land Grant Colleges. Zinser has served as administrator of the School of Medicine at the University of Washington, Seattle; professor and dean of the College of Nursing at the University of North Dakota; vice chancellor for academic affairs at the University of North Carolina, Greensboro; and president of Gallaudet University in Washington, D.C. She earned M.S. degrees from the University of California at San Francisco and from the Massachusetts Institute of Technology and received her Ph.D. degree from the University of California at Berkeley.

James J. Zuiches became dean of the College of Agriculture and Home Economics at Washington State University in July 1995, following his work as program director for Food Systems and Rural Development with the W.K. Kellogg Foundation, Battle Creek, Michigan. When named to the committee, he was director of the Washington State University Agricultural Research Center and associate dean of the College of Agriculture and Home Economics. Zuiches has also been a research administrator with Cornell University and with the National Science Foundation. He received his M.S. and Ph.D. degrees in sociology from the University of Wisconsin, Madison, and has been most active as a teacher and as a researcher in population studies, migration models, and rural development.

ABOUT THE STAFF

Nicole Ballenger is deputy director of the Commercial Agriculture Division at the U.S. Department of Agriculture's Economic Research Service (ERS). She directed the land grant study under the terms of an Intergovernmental Personnel Act Agreement between the ERS and the National Research Council. Ballenger has a Ph.D. degree in agricultural economics from the University of California at Davis. Her areas of economics research include U.S. agricultural and food policy, international trade, agriculture in developing countries, and linkages between trade and the environment. During 1990–1991 she was senior staff economist for agriculture and trade for the President's Council of Economic Advisers.

Carla Carlson is director of communications at the Board on Agriculture, where she is responsible for the writing, editing, review, production, and dissemination of reports. She coordinated public forums in the states as part of the land grant study. Prior to coming to the National Research Council, she was science correspondent for the U.S. Information Agency's wire service and associate editor of *SciQuest* magazine. She is an officer of the D.C. Science Writers' Association and a member of its board of directors. She has degrees in journalism and biology from South Dakota State University.

Viola Horek is administrative assistant at the Board on Agriculture and senior project assistant for the Committee on the Future of the Land Grant Colleges of Agriculture. From 1990 to 1993 she worked for the city of Stuttgart, Germany, as urban planner and earlier was employed by the Department of Defense in Germany. She received her M.A. degree in architecture and urban planning from the University of Stuttgart.

Diby Kouadio is a research associate for the Board on Agriculture's study of the land grant colleges of agriculture. He earned his M.S. degree in agricultural economics from the University of Illinois at Urban-Champaign and his Ph.D. degree in agricultural economics from The Pennsylvania State University. Kouadio's economics research interests relate to policy intervention in world commodity markets. He is a member of the American Agricultural Economics Association and the National Society for Minorities in Agriculture, Natural Resources and Related Sciences.

Janet Overton has edited the Board on Agriculture's major reports since 1991. Earlier, she was production editor with scientific publisher Marcel Dekker, Inc., and production editor at the *Proceedings of the National Academy of Sciences*. She has also consulted and freelanced for a number of publishing houses including Random House, D. Van Nostrand, Springer-Verlag, and Prentice-Hall. Overton holds a M.F.A. degree in play writing from Columbia University. She is a published playwright and script reader for professional theaters.

Index

A

access to education, 46-48
  minority enrollments, 55-56
African-Americans
  1890 colleges, 1, 15, 47
Agency for International Development, U.S., 2
alternative agriculture, 18

B

Bailey, Liberty Hyde, 90
Bankhead-Jones Act, 14
biotechnology, 22-23, 30
  technology transfer, 97
bridging agreements / programs, 5, 31, 32, 56

C

capacity building programs, 56
challenge grants, 50-51
  application, 14 n.2
  current institutional spending, 52
  for innovative teaching, 5, 8, 65
checkoff funding, 82
collaborative research and development agreements, 83
competitive grants
  alternative allocation mechanisms, 83-84
  characteristics, 78
  current federal allocation, 9, 73
  equitable distribution, 79-80
  experiment station research, 28
  for extension, 103
  recommendations for, 5, 9, 12, 75-80, 103
Congress, U.S., food and agriculture advisory boards, 26-27
consumers
  in food and agriculture system, 3, 22, 25
  research agenda and, 97
cooperative extension. *see* extension activities; extension funding
Current Research Information System (CRIS), 26, 73

D

Department of Agriculture, U.S.
  college and university spending, 50, 52
  current research spending, 9
  intramural research, 14 n.1, 73
  in LGCA system management, 2, 14
  recommendations for institutional linkages, 8
  research spending, 73-80
diet and health, 15-17, 25
  extension activities, 91
  as multidisciplinary science, 101
distance learning
  applications, 35, 36
  recommendations for, 4, 33

E

economic development, 100
education
  curriculum revitalization projects, 61
  environmental/natural resource, 62-65
  faculty characteristics, 56-58
  faculty exchanges, 56
  federal role, 50-51
  lifelong, 39
  minority student enrollment, 55-56

in non-land grant schools, 62
of foreign students, 48
problem-solving orientation, 60, 65-67
program design, 59-62
rationale for LGCA system, 46-50
recommendations for, 67-68
student characteristics, 53, 55
student exchanges/transfers, 56
student recruitment, 54
tuition and fees, 48
USDA spending, 50-51
see also teaching
1890 colleges, 1, 15, 30, 32, 47
current status, 80
extension activities, 95
funding, 5, 6, 7, 12, 80, 95
recommendations for, 5, 6, 7, 12, 80-81
research activities, 80
student enrollment, 55-56
1862 colleges, 1, 15
in regionalization of LGCA system, 32
tuition and fees, 48
electronic technology
for education, 34, 35
geographic information systems, 55
Elementary and Secondary Education Reauthorization Act, 15, 56
employment trends, 1, 3, 13, 15
demand for food and agriculture graduates, 51
environmental concerns, 15, 18, 22
academic programs, 62-65
extension activities and, 96-97
as rationale for federal involvement in extension, 90-91
EPSCoR. *see* Experimental Program for Stimulating Competitive Research
ESCOP. *see* Experiment Station Committee on Organization and Policy
Experiment Station Committee on Organization and Policy (ESCOP), 27-28
Experimental Program for Stimulating Competitive Research (EPSCoR), 5, 79
extension activities
consumers of, 25
cooperative vs. university extension, 87, 88
current context, 87, 92
federal role, 90-92
future prospects, 93-94
historical development, 93
information management, 91-92
integration with research and teaching activities, 37-41, 42, 89, 91
interpretation of regulations as, 89
LGCA system mission, 14
national interest and, 88-89
non-USDA federal agency interests in, 92
nonfarm/nonrural, 6, 94, 98-101, 102
opportunities for improvement, 87-88
oversight, 10-11
performance evaluation, 43, 91-92
private-public collaboration for, 96
private vs. public roles, 94-95
privatization of, 11
recommendations for, 6-7, 92, 101-104
regional diversity, 103
regional market-based, 34-35
research base, 6, 9, 101
role of, 87, 96-98
rural economic development, 100
extension funding
accountability, 91
allocation, 102-104
for 1890 colleges, 95
extension research focus and, 39
for nonfarm activities, 98
recent trends, 90
recommendations for, 4-7, 8-9, 11, 102-104
return on investment, 89
USDA, 50

F

faculty
appointment trends, 38
demographics, 56-58
incentives for, 58-59
student contacts, 58
farms
current characteristics, 2, 14-15, 18, 23-24, 92
diversity, 28-29
incomes, 23
knowledge sources, 92
niche markets, 24
population trends, 1, 13, 15, 93
rural economic development as extension activity, 100
specialization, 94
technological change, 16-17
see also industrial agriculture
Federal Coordinating Council for Science, Engineering, and Technology, 51
federal government
congressional advisory bodies on food and agriculture, 26-27
in extension system, 90-92, 94-96, 98
in food and agriculture education, 50-51
in food and agriculture research, 72-80
interpretation of regulations as extension activity, 89
justification for involvement of, 43-45
in LGCA system funding, 2, 9-11, 36
in LGCA system management, 1-2, 18-19
non-USDA agencies, 6, 8, 75, 92
oversight activities, 10-11
program evaluation, 42-43
Food, Agriculture, Conservation, and Trade Act, 19, 73
food safety, 25, 60
food stamp program, 23
foreign students, 48
formula funding
accountability, 75
advantages of, 74-75, 103
allocation system, 33, 73-74
current federal spending, 19, 73
disadvantages of, 75, 103
for extension, 103

for integrative activities, 42
recommendations for, 9-10, 12, 33, 103
4-H clubs, 54
funding
accountability, 41-45
allocation, 2, 3-11, 14, 28-29, 40-41
for development of teaching practice, 5
LGCA system, 2, 14
oversight, 10-11
private sector research spending, 30
recommendations for federal contribution, 9-11, 33
recommendations for state contributions, 6, 81
regional projects, 8, 33
sources, 2, 19
USDA spending for colleges and universities, 50
see also competitive grants;
formula funding

G

genetic engineering. *see* biotechnology
geographic information systems, 55
Government Performance and Results Act, 42-43
Green Revolution, 69

H

Hatch Act of 1887, 1, 14, 16, 73

I

independent crop consultants, 97
industrial agriculture, 18
characteristics, 23
development of, 23, 24
educational needs, 60
extension needs, 94
information management
Current Research Information System, 26, 73
extension system, 6, 91-92
recommendations for, 6, 92
integrated pest management, 96-97
intellectual property rights/patents, 23, 81, 82
inter- and multidisciplinary learning/research, 4, 5, 8, 35-36, 65 , 85
food and nutrition science, 101
international context
academic programs, 60
privatization of extension, 94
research needs, 69-70
U.S. agriculture in, 17, 22
Internet, 8, 31, 35
internships, 60
recommendations for, 5, 62

J

Joint Council on Food and Agricultural Sciences, 26-27

L

land grant college of agriculture system
access, 46-48, 55-56
contextual analysis, 21
cooperation within, 5, 7-8, 32, 39
current context, 2-3, 14-18
founding mandate, 1, 13-14, 46
historical development, 47
legislative history, 18-19
opportunities for improvement, 3-12
organizational structure, 1-2
rationale for teaching component, 46-50
smaller institutions, 32
stakeholder participation in, 3, 4, 25-28
unique features, 10-11
see also organizational structure of LGCA system
LGCA system. *see* land grant college of agriculture system
Lincoln University, 55

M

market characteristics
consumer behavior, 22
global context, 17, 22
regional extension based on, 34-35
minority populations
agriculture student enrollment, 55-56
educational grants, 52
faculty demographics, 56-58
recommendations regarding, 7
Morrill Act
of 1862, 1, 13, 14, 15, 47
of 1890, 1, 15
Morrill-Nelson Grants, 14 n.2, 50
Multicultural Scholars Program, 52

N

National Agricultural Research, Extension, and Teaching Policy Act, 18
National Agricultural Research and Extension Users Advisory Board, 27
National Association of State Universities and Land Grant Colleges, 27-28
national economy, agricultural component of, 15, 16
National Initiative for Research in Agriculture, Food, and the Environment, 5, 19, 28, 75
National Institutes of Health, 2, 75, 78
national interest, 3
extension activities and, 11, 88-89
in food and agriculture education, 47-50
in food and agriculture research, 69-70
in food and agriculture system, 10-11, 15-17, 29
program evaluation in terms of, 41-45
stakeholder participation in food and agricultural system, 3, 25-28
National Science Foundation, 2, 75
Native Americans, 7, 15, 56, 57

New Mexico State University, vii
new geography, 7-8, 30-31
  rationale, 31-33
1994 colleges, 7, 15

O

organizational structure of LGCA system
  current, 30
  federal role, 18-19
  federal-state partnership, 1-2, 14
  integration of functions in, 4, 8-9, 37-41, 42, 91
  intramural issues, 37
  recommendations for new geography, 7-8, 30-33
  for research, 73
  role of colleges in, 11
  stakeholder participation in, 3, 25-28

P

patents. *see* intellectual property rights/patents
population
  farm, 1, 13, 15, 93
  world trends, 17
poverty, 23
private sector
  independent crop consultants, 97
  LGCA research funded by, trends in, 81
  public partnerships for research, 81-82
  research activities, 18, 29-30
  role in extension system, 94-96
privatization
  definition, 94
  of extension activities, 11, 94-95
  of research activities, 29-30
Project Sunrise, 61
public goods concept, 43-44
Purnell Act, 18

R

regional activities/approach
  diversity in extension system, 103-104
  market-based extension, 34-35
  rationale, 33
  rationale for federal involvement in extension, 90-91
  recommendations for, 4, 7-8, 30-36
  research resource allocation, 33
  teaching practice, 34
research activities
  adaptive, 71-72
  as cascade of knowledge, 70, 71
  consumer influence, 97
  continuum, 70-72
  dissemination of findings, 72
  economic models, 16-17
  at 1890 colleges, 80
  evaluation of, 5, 10-11, 26, 41-45, 73
  extension support, 6, 9, 101
  fundamental, 70, 72
  integration with extension and teaching activities, 37-41, 42, 89, 91
  integrative, 70-71
  intellectual property rights, 23, 81, 82
  national interest in, 69-70
  organizational structure, 73
  private sector, 18
  proposal writing, 83
  recommendations for, 4, 29-30, 85-86
  resource allocation, 25-26, 28, 32
  social rate of return, 70, 85
  specialization, 31-32, 34
  students in, 40
  USDA intramural, 14 n.1
Research and Marketing Act, 18
research funding
  allocation mechanisms for competitive grants, 83-84
  chunk grants, 83-84
  federal role, 72-73
  federal spending, 9, 73-80
  inter- and multidisciplinary, 85
  percentage funding methods, 84
  performance-based, 84
  preproposal review method, 83
  private-public partnerships, 81-82
  recommendations for, 4-6, 8-9
  USDA, 50
  via checkoff funding, 82
Roosevelt, Theodore, 90, 93

S

small-business innovation research grants, 83
Smith-Lever Act of 1914, 1, 14, 98
South Dakota State University, 57
specialization
  information needs of farmers, 94, 96
  in LGCA system, 31-32, 34
  of research scientists, 38-39
state government
  extension funding, 95
  funding of 1890 colleges, 80, 81, 95
  justification for involvement of, 45
  LGCA system funding by, 2, 19, 80, 81
  in LGCA system management, 1-2
  multistate issues, 31
  recommendations for, 6, 95
Sustainable Agriculture Research and Education Program, 33

T

teaching
  computer technology for, 34
  encouraging innovation in, 5, 8, 65
  faculty-student contacts, 58
  federal grants for, 50-51
  integration with extension and research activities, 37-39, 42
  regional coordination, 34
  science education through agriculture, 66
  student internships, 5, 60

systems approach, 64
transdisciplinary program, 63
tuition and fees, 48
Tuskegee University, 1

U

university extension, 87, 88
University of California at Davis, 64, 67
University of California at Santa Cruz, 88
University of Connecticut, vi
University of Maryland, 63
University of Minnesota, 61
University of Nebraska, 61
University of Washington, 88
University of Wisconsin, 61
urban/suburban areas
agriculture student recruitment in, 54
extension activities, 94, 98-102
LGCA system and, 32-33

V

von Liebig, Justus, 16

W

W. K. Kellogg Foundation, 25, 61

Recent Publications of the Board on Agriculture

POLICY AND RESOURCES

Ecologically Based Pest Management: New Solutions for a New Century (1996), 152 pp., ISBN 0-309-05330-7
Colleges of Agriculture at the Land Grant Universities: A Profile (1995), 146 pp., ISBN 0-309-05295-5
Investing in the National Research Initiative: An Update of the Competitive Grants Program in the U.S. Department of Agriculture (1994), 66 pp., ISBN 0-309-05235-1
Rangeland Health: New Methods to Classify, Inventory, and Monitor Rangelands (1994), 180 pp., ISBN 0-309-04879-6
Soil and Water Quality: An Agenda for Agriculture (1993), 516 pp., ISBN 0-309-04933-4
Managing Global Genetic Resources: Agricultural Crop Issues and Policies (1993), 450 pp., ISBN 0-309-04430-8
Pesticides in the Diets of Infants and Children (1993), 408 pp., ISBN 0-309-04875-3
Managing Global Genetic Resources: Livestock (1993), 294 pp., ISBN 0-309-04394-8
Sustainable Agriculture and the Environment in the Humid Tropics (1993), 720 pp., ISBN 0-309-04749-8
Agriculture and the Undergraduate: Proceedings (1992), 296 pp., ISBN 0-309-04682-3
Water Transfers in the West: Efficiency, Equity, and the Environment (1992), 320 pp., ISBN 0-309-04528-2
Managing Global Genetic Resources: Forest Trees (1991), 244 pp., ISBN 0-309-04034-5
Managing Global Genetic Resources: The U.S. National Plant Germplasm System (1991), 198 pp., ISBN 0-309-04390-5
Sustainable Agriculture Research and Education in the Field: A Proceedings (1991), 448 pp., ISBN 0-309-04578-9
Toward Sustainability: A Plan for Collaborative Research on Agriculture and Natural Resource Management (1991), 164 pp., ISBN 0-309-04540-1
Investing in Research: A Proposal to Strengthen the Agricultural, Food, and Environmental System (1989), 156 pp., ISBN 0-309-04127-9
Alternative Agriculture (1989), 464 pp., ISBN 0-309-03985-1
Understanding Agriculture: New Directions for Education (1988), 80 pp., ISBN 0-309-03936-3
Designing Foods: Animal Product Options in the Marketplace (1988), 394 pp., ISBN 0-309-03798-0; ISBN
Agricultural Biotechnology: Strategies for National Competitiveness (1987), 224 pp., ISBN 0-309-03745-X 0-309-03795-6 (pbk)
Regulating Pesticides in Food: The Delaney Paradox (1987), 288 pp., ISBN 0-309-03746-8
Pesticide Resistance: Strategies and Tactics for Management (1986), 480 pp., ISBN 0-309-03627-5
Pesticides and Groundwater Quality: Issues and Problems in Four States (1986), 136 pp., ISBN 0-309-03676-3
Soil Conservation: Assessing the National Resources Inventory, Volume 1 (1986), 134 pp., ISBN 0-309-03649-9; Volume 2 (1986), 314 pp., ISBN 0-309-03675-5
New Directions for Biosciences Research in Agriculture: High-Reward Opportunities (1985), 122 pp., ISBN 0-309-03542-2
Genetic Engineering of Plants: Agricultural Research Opportunities and Policy Concerns (1984), 96 pp., ISBN 0-309-03434-5

NUTRIENT REQUIREMENTS OF DOMESTIC ANIMALS SERIES AND RELATED TITLES

Nutrient Requirements of Laboratory Animals, Fourth Revised Edition (1995)., 176 pp, ISBN 0-309-05126-6
Metabolic Modifiers: Effects on the Nutrient Requirements of Food-Producing Animals (1994), 81 pp., ISBN 04997-0
Nutrient Requirements of Poultry, Ninth Revised Edition (1994), ISBN 0-309-04892-3
Nutrient Requirements of Fish (1993), 108 pp., ISBN 0-309-04891-5
Nutrient Requirements of Horses, Fifth Revised Edition (1989), 128 pp., ISBN 0-309-03989-4; diskette included
Nutrient Requirements of Dairy Cattle, Sixth Revised Edition, Update, (1989), 168 pp., ISBN 0-309-03826-X; diskette included
Nutrient Requirements of Swine, Ninth Revised Edition (1988), 96 pp., ISBN 0-309-03779-4
Vitamin Tolerance of Animals (1987), 105 pp., ISBN 0-309-03728-X
Predicting Feed Intake of Food-Producing Animals (1986), 95 pp., ISBN 0-309-03695-X
Nutrient Requirements of Cats, Revised Edition (1986), 87 pp., ISBN 0-309-03682-8
Nutrient Requirements of Dogs, Revised Edition (1985), 79 pp., ISBN 0-309-03496-5
Nutrient Requirements of Sheep, Sixth Revised Edition (1985), 106 pp., ISBN 0-309-03596-1

Further information, additional titles (prior to 1984), and prices are available from the National Academy Press, 2101 Constitution Avenue, N.W., Washington, D.C. 20418; (phone) 202-334-3313 (information only) or 800-624-6242 (orders only); (fax) 202-334-2451; (Internet) http://www.nas.edu/nap.