Gathering Input on a Science Roadmap for Agriculture: Report of Delphi Study

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Introduction

Grand challenges are "unsolved scientific problems of extraordinary breath and importance which will demand continuing…advances throughout the forthcoming…era" (Wilson, p. 171, 1989). A Grand Challenge exhibits at least the following characteristics:

1. "It is demonstrably hard to solve, requiring several orders-of-magnitude improvement in the capability required to solve it.
2. The problem cannot be unsolvable. If it probably can't be solved, then it can't be a Grand Challenge. Ideally, quantifiable measures that indicate progress toward a solution are also definable.
3. The solution to a Grand Challenge problem must have a significant economic and/or social impact" (Lunceford, ¶3, 2001; Nyerges, 2006).

The Experiment Station Committee on Organization and Policy (ESCOP) Science and Technology Committee is charged with "promoting and enhancing science and technology in the Land-grant university system" (ESCOP, ¶1, 2008). The committee helps "identify future directions and anticipate and respond to research needs and opportunities for funding" (ESCOP, ¶1). Following this charge and function, the 2009 Science and Technology Committee provides the following update of the USDA Science Roadmap.

Methodology

Approximately every 5 years the ESCOP Science Roadmap, that provides direction for agricultural research over the ensuing 5-10 years. In order to accomplish this task in 2009, the Delphi methodology was used. The Delphi method is a "set of procedures for formulating a group judgment for subject matter where precise information is lacking" (Dalkey, Brown, & Cochran, 1969, p. 7; Dalkey, 1969). The Delphi technique may used as a to solicit interpretations, predictions, or recommendations (Strauss & Zeigler, 1975), using a purposively selected panel of experts who possesses competence on the question, represent the chosen population, and have been nominated by peers to remove researcher bias (Gordon, 1994). Experts may express a wide range of diverse opinions (Stufflebeam, McCormick, Brinkerhoff, & Nelson, 1985).

Participants included those faculty nominated by the research director within each college of agriculture at all land-grant institutions. In all, 457 nominations were secured by providing the research team with the individual's name and email address. A total of 246 participants responded to the final round of the Delphi (see Table 1).

Table 1

Response rate by round

Round	Response (%)	*n*
1	57.8	264
2	56.9	260
3	54.5	249
4	53.8	246

Participants were asked to complete four rounds of Delphi questionnaires. Questions used in Round 1 were generated from the previous *Science Roadmaps for Agriculture* which was created and updated by ESCOP Science and Technology Committee. Research priority wording remained exactly as presented in previous science roadmaps in nearly all instances. The first three rounds involved participants response to proposed research priorities in a summated rating scale format of (5) *strongly agree* to (1) *strongly disagree*. The final round consisted of a dichotomous *yes-no* format, answering the question as whether to not to include that particular research priority in the updated *Science Roadmap for Agriculture*.

In Rounds 1 through 3, questions with a mean response of greater than 3.0 and standard deviation less than 1.0 were considered accepted and were held for Round 4. Questions with a mean value below 3.0 were dropped from further consideration. In Rounds 1, 2 and 3 respondents were offered the option to reword or add additional relevant and imperative research priorities that they felt were missed in the original survey. For Round 4, the final round, research priorities were retained that garnered greater than 60% consensus among respondents.

June through August 2009, 457 individuals who teach, conduct research and are involved in administration at land grant universities across the nation were asked to complete four rounds of surveying regarding future directions for agricultural research for the next 5-10 years. Using the previous two *Science Roadmaps for Agriculture* as the starting point, participants were asked to identify new research priorities and amend current priorities.

Survey Sample

The research sample was compiled by emailing the ESCOP directors from all land-grant universities across the Nation. In early May an email was sent to ESCOP Directors from all land-grant universities across the Nation. Within this email they were asked to provide the names and contact information of five individuals with great knowledge of current research and issues within the agricultural industry. The director from each university was then also asked to participate. Of the 457 possible participants, 246 (53.8%) completed Round 4 (see Table 1).

On June 9, once the participants' names were compiled, each participant was emailed a welcome letter explaining the study and the basis for their selection. The Round 1 questionnaire was available for completion, on www.surveymokey.com, from June 11 to the 17. The results from Round 1 were then analyzed and the Round 2 questionnaire was created. This was available for completion from June 26 to July 6. Again the results were analyzed and the questionnaire modified to include the reworded research priorities. Round 3 was open from July 10 to July 21. The Round 4 questionnaire was then created in a dichotomous format, asking if the priority was important enough to be included in the updated *Science Roadmap for Agriculture*. Round 4 was available to participants from July 31 through August 10. Participants were notified of a new round of surveying by email the day each round was opened.

Of these 246 respondents over half (59.8%) were primarily involved in administration at their respected universities followed by 20.5% who claimed research as their primary responsibility (see Table 2). Respondents were spread across the country. Respondents were asked to provide what they considered their discipline of study. These were then grouped into 18 categories. While many are simply stated, a few were combinations of more than one type. *Animal science* includes poultry and dairy science, applied ethology, and veterinary medicine. Included in *plant*

science are plant breeding, pathology, and biotechnology. *Natural resources and environmental science* included forestry, watershed management, environmental chemistry, hydrology, toxicology, and resource management. *Agricultural economics* encompasses environmental and resource economics. *Agricultural extension* includes 4-H and cooperative extension. *Food science and nutrition* also consists of food safety. *Family and consumer sciences* are comprised of childhood development and any other mention of family and consumer sciences, while human sciences included rural sociology. *Agronomy and soil sciences* contain any study of crops and soils, range management, and weed science. *Biological sciences* included biology, infectious diseases, and molecular biology. *Human sciences* included human ecology.

Table 2

Respondent Demographics (n = 246).

	Valid Percentage	*n*
<u>Discipline</u>		
Animal science	13.7	31
Plant science	11.9	27
Agricultural economics	10.6	24
Agronomy and soil sciences	10.6	24
Natural resources and environmental science	7.9	18
Food science and nutrition	6.6	15
Agricultural extension	6.2	14
Family and consumer sciences	4.8	11
Microbiology and biochemistry	4.8	11
Entomology	4.4	10
Agricultural and biological engineering	4.0	9
Horticulture	3.5	8
Administration	3.5	8
General agriculture	2.2	5
Human sciences	2.2	5
Agricultural education and communication	1.3	3
Biological sciences	1.3	3
Ecology	0.4	1
No answer or “various”	---	19
<u>Primary Responsibility</u>		
Administration	59.8	137
Research	20.5	47
Teaching	9.2	21
Extension	2.2	5
Other	8.3	19
No Response	---	17
<u>Land-Grant Institution</u>		
1862	85.6	196
1890	12.2	28

	Valid Percentage	*n*
1994	2.2	5
No response	---	17
	Academic Title	
Provost	0.4	1
Dean	7.4	17
Director	20.1	46
Chair	11.4	26
Faculty	26.2	60
Other	34.5	79
No response	---	17
	Geographic Region of the United States	
South	34.5	79
West	32.3	74
Northeast	19.7	45
Central	13.5	31
No response	---	17

Respondents proposed 64 new or revised research priorities garnering over 60% consensus agreement (see Table 3). Of the 28 research objectives proposed in 2006, 15 were retained as research priorities in 2009. Of the research priorities, 38 reached consensus agreement from over 70% of the respondents.

Table 3

Identified Research Priorities with Consensus over 60% (n = 240).

Research Priority[a,b]	Consensus (% *yes*)	*n*
Develop Renewable Energy and Biofuel Systems		
Develop and implement the use of alternative energy sources for agricultural purposes including, but not limited to, wind energy, biofuel, methane production, and small-scale hydroelectric, geothermal, solar, and tidal energy.	88.8	213
Develop agricultural systems that utilize inputs efficiently and create fewer waste products, especially by converting "traditional" waste products into biomass fuels and by developing secondary uses and markets for current agricultural waste products.	85.0	204
Assess the environmental, sociological, and economic impacts from the production of biofuels and co-products at local and regional levels to ensure sustainability.	77.9	187
Develop technologies to improve production-processing efficiency of regionally appropriate biomass into by-products (including biofuels).	77.3	186
Expand biofuel research with respect to non-arable land, algae, pest issues that limit biofuel crop yields, and emissions of alternative fuels.	73.8	177
Investigate the opportunity costs of biofuel production from food crops, agricultural waste, and other sources.	71.7	172

Research Priority[a,b]	Consensus (% *yes*)	*n*
Average of research priorities for the Grand Challenge	79.1	
Manage Agricultural Water Usage		
Create new and/or modify existing profitable agricultural and natural resource systems that conserve use of and recycle water.	85.8	206
Develop technologies to improve production efficiencies of use distribution and quality of water.	85.0	204
Research the effects of global climate change with regard to water usage for agricultural production and processing methods.	77.1	185
Evaluate and enhance the water recharge value of agricultural and forestry production areas.	72.1	173
Examine the policy and legal issues relating to water use, distribution, and quality.	70.8	170
Average of research priorities for the Grand Challenge	78.2	
Develop Agricultural Systems for a Changing Global Climate		
Explore relationships between global climate change, climate variability, invasive species, native species, and crop and livestock responses.	79.2	190
Develop biotechnologies that enable enhanced production of food, adaption of animal and plant food systems to face global climate change, utilization of integrated pest management, and negotiation of socioeconomic challenges to the food system.	78.3	188
Explore production systems that enhance the economic viability, improve efficiency, and/or reduce emissions of methane or other greenhouse gasses.	74.2	178
Research breeding programs, local practices, and pest and disease management systems that help animal and plant agriculturalists adapt to global climate change.	73.8	177
Analyze the impacts of carbon policy on agriculture and the food system and develop strategies to help producers and processors in agriculture, natural resources, and food industries benefit from carbon trading and ecosystem service markets.	69.6	167
Average of research priorities for the Grand Challenge	75.0	
Develop New Plant Products, Uses, and Crop Production Systems		
Improve crop productivity with limited inputs of water and nutrients through enhanced efficiencies, plant biology, and innovative management systems.	90.8	218
Develop strategies to enhance energy efficiency in agricultural production systems.	83.8	201
Develop technologies to improve processing efficiency of crop bioproducts (eg. biofuels, pharmaceuticals, functional foods).[5b]	74.6	179
Investigate the interdependency of multiple land use decisions, including food, fiber, biofuels, and ecosystem services.	71.7	172
Assess the benefits and cost of decreasing the dependency on synthetic, petroleum-based chemicals in the agricultural industry.	64.2	154
Conceive new markets for new plant products and new uses for those crops.[5a]	61.3	147
Average of research priorities for the Grand Challenge	74.4	
Enhance Production of Safe and Abundant Food		
Develop methods to prevent, detect, monitor, control, and respond to potential food safety hazards in the production and processing of food crops and livestock grown under all production systems.	86.3	207
Develop food systems and technologies that improve the nutritional values, diversity,	82.9	199

Research Priority[a,b]	Consensus (% *yes*)	*n*
and health benefits of food.[1b]		
Develop strategies to detect and eliminate food-borne illnesses, bioterrorism agents, invasive species, and pathogens affecting plants, humans, and animals.[1d]	80.8	194
Decrease dependence on chemicals with harmful effects to people and the environment by optimizing effective crop, weed, pest, and pathogen management strategies.	71.3	171
Identify plant compounds that prevent human diseases (ex. cancer), and develop and encourage methods to enhance or introduce these plants and compounds into the food system.	65.8	158
Establish plant and animal breeding programs that balance and optimize nutritional value to complement production characteristics.	62.1	149
Examine the impact of the food supply changes and food transportation relative to preservation practices, safety, and energy efficiency at local and regional scales.	61.7	148
Average of research priorities for the Grand Challenge	73.0	
Develop New Animal Production Practices, Products, and Uses		
Promote animal health and well-being in all production systems through enhanced nutrition, efficiency, utilization of non-traditional feeds, genetics, and disease reduction.	77.5	186
Develop new and enhanced technologies for the improved efficiency and welfare of animals that are processed for food.[7c]	66.7	160
Average of research priorities for the Grand Challenge	72.1	
Improve the Economic Return to Agricultural Producers		
Develop sustainable production systems that are profitable, productive, and include integration of crop and livestock production systems.[3a]	81.7	196
Provide evidence-based recommendations for alternatives to the current price support system that encourage agricultural production.	76.7	184
Explore the use of alternative economic models for stimulating farming through the use of farmer supports besides price supports.	68.3	164
Support the development of marketing infrastructure for crop bioproducts.	60.4	145
Average of research priorities for the Grand Challenge	71.8	
Maintain a Sustainable Environment		
Develop efficient and sustainable farming and food processing systems that rely on renewable energy systems and decrease the carbon footprint, particularly those systems that convert agricultural wastes into biomass fuels that further improve the efficiency of production.	83.8	201
Develop environmentally friendly crop and livestock production systems that utilize sustainable feeding and pest management strategies.[2c]	76.7	184
Develop methods to protect the environment both on and beyond the farm from any negative impacts of agriculture through optimum use of cropping systems including agroforestry, phytoremediation, site-specific management, multicrop polyfarms, and perennial crops.[2a]	73.8	177
Develop innovative technologies for reducing the impact of animal agriculture on the environment.	73.8	175
Develop strategies, ecological and socioeconomic system models, and policy analyses to address conservation, biodiversity, ecological services, recycling, and land use policies.[2d]	67.9	163

Research Priority[a,b]	Consensus (% *yes*)	*n*
Develop agricultural systems that create fewer waste products.[2b]	64.2	154
Create a clear understanding of the principles and facets underlying the concept of sustainability as it relates to urban and rural agriculture.	62.5	150
Average of research priorities for the Grand Challenge	71.8	
Enhance the Uses of Biotechnology		
Develop and assess the impact of nanotechnology for pathogen and pest identification, detection, and eradication, with the overall goal of improving human health.	78.3	188
Assess the safety and effectiveness of genetically-engineered organisms on human and environmental health.	77.1	185
Assess the safety of nanotechnologies and nanomaterials on human and environmental health.	68.8	165
Integrate nanotechnologies into agricultural and food production practices.	61.3	147
Average of research priorities for the Grand Challenge	71.4	
Increase Public Awareness of Food, Fiber and Fuel Production		
Increase public awareness of agricultural production and processing – including traditional and organic methods — and the societal and environmental benefits and consequences of agriculture.	74.2	178
Discover effective educational methods to help individuals make informed and healthy food choices.	73.3	176
Understand the behavioral and educational dimensions (personal, consumption, and policy) that influence personal and family dietary and health decision-making to reduce public health issues, such as obesity.	70.4	169
Conduct research on the relationship between food consumption, portion size, exercise, and obesity, and build extension programs that lead to behavior change regarding eating habits.	64.6	155
Average of research priorities for the Grand Challenge	70.6	
Improve the Productivity of Organic and Sustainable Agriculture		
Research feasibility and sustainability of organic and non-organic systems, especially as related to population growth and future food needs.	72.5	174
Develop improved pest, weed, and disease control and management strategies for organic production.	72.1	173
Examine the optimal conservation, environmental, and production outcomes—including sustainability, nutrition content, profitability, and energy efficiency—for organically produced agricultural products.	65.8	158
Average of research priorities for the Grand Challenge	70.1	
Develop Human Capital and Capacity in Agriculture		
Develop farming systems that increase economic viability, social acceptability, and environmental quality of all participants in the agricultural system.	73.8	177
Identify and assess avenues by which beginning farmers can access necessary education, land, and/or capital to overcome barriers.	67.9	163
Conduct research on the retention of existing and development of new human capital in agriculture.	60.0	144
Develop educational programs that build food production capacity and are focused	60.0	144

Research Priority[a,b]	Consensus (% *yes*)	*n*
on assistance to ethnic, immigrant, underserved, urban, and/or economically disadvantaged populations interested in entering food production.		
Average of research priorities for the Grand Challenge	65.4	
Sustain Individual, Family, and Community Resilience		
Determine strategies to enhance the well-being of families and individuals, including those strategies that ensure access to high-quality food, health care, education, social services, and a clean, healthy environment.[4d]	75.4	181
Explore ways to introduce and measure the impact of rural and urban agricultural education, natural resources education, and food literacy education in all high schools across the Nation.	66.3	159
Increase assistance to 4-H programs, FFA, and private sector youth programs that integrate environmental and agricultural topics into their curriculum.	65.8	158
Examine the economic impact of entrepreneurship and business development on rural communities, and develop new forms of economic activity built around regional trade associations, rural cooperatives, and local production networks.[4a]	62.1	149
Assess strategies for building coalitions among agricultural, environmental, academic, governmental, labor, and community development groups to facilitate scientifically sound social change in rural communities.[4b]	61.7	148
Investigate means of enhancing the problem-solving capacities of rural communities through developing leadership, implementing action plans which strengthen family and community resilience, and negotiating urban-rural interface issues.[4c]	61.3	147
Develop strategies for integration of local, regional, national, and global food systems to maximize the benefits to both U.S. and global agriculture, particularly in underserved and immigrant populations.[3b]	60.8	146
Average of research priorities for the Grand Challenge	64.8	

[a] Grand Challenges are listed in order of mean level of agreement of the priorities reaching 60% consensus under each, and the research priorities are listed according to their importance under each Grand Challenge.

[b] Denotes repeated research priority from 2006 *Science Roadmap for Agriculture*. These are denoted with their challenge and objective number from Table 2 of the 2006 *Science Roadmap for Agriculture*.

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