THE ROLE OF IMPROVED IRRIGATION TECHNOLOGIES IN HELPING FARMERS MEET ENVIRONMENTAL AND ECONOMIC CHALLENGES

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Innovative irrigation technologies and practices can play an important role in helping farmers meet the need to conserve water, mitigate adverse impacts on water quality and be more competitive in an increasingly global economy, according to a panel of irrigated agriculture experts participating in a Sept. 9, 1996, briefing sponsored by the Environmental and Energy Study Institute (EESI).

Two recent reports on irrigation support this conclusion: "A New Era for Irrigation" by the National Research Council's Water Science and Technology Board (NRC report) and "Future of Irrigation" by the Council for Agricultural Science and Technology (CAST report). The CAST report focuses on the future of irrigated agriculture in the western states, while the NRC report looks at the future of all types of irrigation, both agricultural and turf, across the nation.

The NRC report concludes that "[a]dvances in irrigation technology are necessary if both agricultural and turf irrigation are going to adapt to changing demands and changing supplies," but "[t]he irrigation industry will need to play a larger role in technology development and dissemination as the federal government trims its support for these activities."

Similarly, the CAST report concludes that "[i]ncreased investment in agricultural research and development will benefit all regions of the West" by helping growers adapt to an increasingly urbanized population and by enhancing their ability to compete in global food and fiber markets. It further concludes that "[b]oth private and public investment will be important" in helping growers adapt.

WHAT ARE THE CHALLENGES FACING IRRIGATED AGRICULTURE?

Together, the NRC and CAST reports identify the primary challenges facing irrigated agriculture:

- intensified competition for existing water supplies;
- less favorable conditions for developing additional water supplies;
- continued overdraft of ground water;
- increasing public concern for protecting the environment;
- less favored treatment in federal agricultural, environmental and water policies;
- increased competition from the shift to a more global agricultural economy; and
- unresolved Indian reserved water rights claims in the West.

Competition for Water Supply: Population growth, along with support for environmental protection and restoration, have increased competition with agriculture for the use of water, according to the NRC report. "[G]iven the increasing competition for water, changes in how water is managed, allocated and valued are inevitable," the report concludes.

In the West, population growth is faster than the national average, with most new residents settling in urban areas, according to the CAST report. This growing urban population competes with agriculture for water to serve municipal and industrial uses. Urban irrigation of lawns, parks, golf courses and roadside landscaping account for much of the public municipal consumptive use of water, according to the NRC report.

The growing urban population's demand for water to support environmental uses, such as in-stream flows, is likely to have a greater impact on irrigated agriculture than the urban water demand for municipal and industrial uses, according to the CAST report.

Availability of Water: The irrigation industry has long known that population growth is going to quickly outstrip water supply growth, Tom Kimmell, executive director of the Irrigation Association, stated at the EESI briefing.

In the past, new demands for water have been met by developing additional water supplies, such as dam storage, interbasin conveyance facilities and ground water pumping. But today, the NRC report notes that opportunities to develop additional water supplies are limited by financial and environmental concerns. As a result, interest has increased in the potential for reallocating current water supplies, particularly from irrigated agriculture, to new uses and using existing supplies more efficiently, the report concludes

Ground Water Overdraft: Ground water overdraft occurs when water is extracted from an aquifer at a rate greater than the rate at which it is replenished. If ground water is not replenished over the long term, the water table drops and the cost of pumping water to the surface increases. At some point, it is no longer economical to pump water and farmers must turn to dryland farming or the development of supplemental surface supplies, the CAST report notes.

To some extent, ground water overdraft occurs throughout the West except in the Upper Colorado/Great Basin regions and California's Imperial Valley, according to the CAST report. The problem of ground water overdraft is most notable in the Great Plains where several states draw on the Ogallala aquifer, in the Central Valley of California, and in central and southern Arizona, according to the CAST and NRC reports.

Farmers over the Ogallala aquifer have been pumping 12 to 40 times more water than is recharged, states the NRC report. Because recharge is negligible in most areas, "mining of the aquifer will continue to reduce water availability, reduce well yields, and increase pumping lifts," it concludes.

Growing Environmental Concerns: In addition to facing the challenge of greater competition for water to supply environmental needs — such as instream flows for fish, and wetlands for wildlife habitat — farmers will face pressure to reduce agricultural impacts on water quality, according to the two reports.

Water quality is adversely affected by agricultural chemicals, such as pesticides and fertilizers, running off into surface waters and leaching into the ground water, along with soil erosion and leaching of naturally occurring contaminants, such as selenium, from the soil. In some areas, irrigation increases the soil salinity of farmland.

Farmers who must mitigate impacts to water quality and soil salinization will incur higher costs of production, the CAST report notes.

In addition to raising short-term economic concern for farmers, environmental issues raise long-term concern for sustainability, states the NRC report. Investments in technological improvements will help farmers meet environmental requirements and enhance the long-term sustainability of agriculture, the report concludes.

Shifting Federal Policies: Policies and laws favorable to irrigated agriculture are being re-evaluated and modified, such as the subsidies for crop prices and federally supplied irrigation water, and agriculture's exemption from environmental regulation, notes the NRC report.

With this trend in less favorable water, agricultural and environmental policies, along with devolution of responsibility to states to develop and manage water resources, the production costs of farmers will increase, notes the CAST report. These costs need to be offset with innovative technology and management schemes, it notes.

Globalized Agricultural Economy: Today, with the North American Free Trade Agreement (NAFTA) and General Agreement on Tariffs and Trade (GATT), agricultural trade is becoming increasingly global, according to both the CAST and NRC reports. In a global economy, new markets for U.S. products will open up abroad and, at the same time, the domestic market will become more competitive, the NRC report states.

With the shift toward globalization, along with less favorable governmental protection and support for individual farmers, farmers will face increased levels of risk and uncertainty, the NRC report concludes.

IRRIGATION IN THE UNITED STATES: A SNAPSHOT

Leading Irrigation States

By number of acres irrigated in 1992, the 20 leading irrigation states are, in decending order, California, Nebraska, Texas, Idaho, Colorado, Arkansas, Kansas, Montana, Florida, Washington, Oregon, Wyoming, Utah, Arizona, Louisiana, Mississippi, New Mexico, Georgia, Missouri and Nevada. Source: U.S. Census Bureau's *Farm and Ranch Irrigation Survey (1994)* (Census Survey).

Irrigated Lands

Approximately 24% of the farm land in the 48 conterminous states is irrigated. Source: Census Survey.

Approximately 94% of the irrigated acreage in these 48 states lies within the 20 leading irrigation states, while approximately 70% lies within the 17 western states. Source: Census Survey.

Federal Water in the West

The U.S. Department of the Interior's Bureau of Reclamation supplies water to approximately 25% of the irrigated land in the 17 western states. Source: U.S. Department of Interior, Bureau of Reclamation's *Final EIS for Acreage Limitation and Water Conservation Rules and Regulations*, February 1996.

Productivity of Irrigated Lands

Irrigated farms produce approximately 60% of the total crops harvested in the United States and approximately 30% of farm revenues. Source: Joe Goecke, president of Valmont Irrigation, an irrigation manufacturing company.

Water Use and Consumptive Use

Irrigation uses approximately 41% of the fresh water withdrawn from surface and ground water in the 48 conterminous states. In the 20 leading irrigation states, this figure is about 40%; in the 17 western states, this figure is about 36%. In addition to irrigation, fresh water is withdrawn for hydroelectric, public supply, industrial, livestock, domestic, mining and commercial uses. Source: U.S. Geological Survey's *Estimated Use of Water in the United States in 1990* (USGS).

Irrigation is responsible for approximately 81% of the total consumptive use of fresh water withdrawn from surface and ground water in the 48 conterminous states. In the 20 leading irrigation states, this figure is about 97%; in the 17 western states, this figure is about 87%. Source: USGS.

Source and Disposition of Irrigation Water

Nationwide, approximately 63% of the water for irrigation comes from surface water, and approximately 37% comes from ground water. Source: USGS.

Of the fresh water withdrawn from surface and ground water for irrigation, approximately 56% is consumed by crops or otherwise removed from the immediate water environment; approximately 20% is lost during conveyance by leakage or evaporation; and 24% returns to surface or ground water flows. Source: USGS.

Prices for food and fiber are likely to become more variable, according to the CAST report.

The impact of a globalized economy will affect farmers differently according to the type of crop produced. While specifics are hard to predict, by and large, the producers of high-value vegetable and fruit and other labor-intensive crops will face increased competition, according to both reports. On the other hand, producers of grains, oilseeds and livestock are likely to benefit from opening global markets, according to the CAST report.

U.S. technological superiority will help adversely affected farmers to adapt and adjust, the CAST report notes.

Farmer Production Costs: The profitability of irrigated agriculture depends on the price received for crops produced and the costs of production.

The costs of production depend on the costs of capital, labor and energy, along with other inputs such as irrigation equipment, water and water management, seed, fertilizer and pest control, according to the CAST and NRC reports. Among other factors, profitability depends on available technology and management skills, notes the NRC report.

Modest increases in irrigation costs can tip the balance regarding profitability, the CAST report concludes.

Water Costs: According to the two reports, direct water costs may increase for farmers who depend on federally subsidized water from the U.S. Department of Interior's Bureau of Reclamation (BuRec) and those who pump ground water. (See side bar on "Irrigation in the United States: A Snapshot.") Federally subsidized water from BuRec could become more expensive as political pressure builds to eliminate or reduce subsidies, according to the CAST report. Ground water pumping is directly affected by energy costs, which are influenced by both energy prices and the level of the aquifer, according to the NRC report.

Farm Revenues: "[M]ost analysts expect revenues from agricultural

production to decline due to less favorable government policies toward agriculture and increased global competition in the production of food and fiber," states the CAST report.

Nonetheless, "continued investment in agricultural research and development holds the prospect of stabilizing or lowering the real costs of production so that net returns to irrigated agriculture need not shrink and may grow," the report concludes.

Native American Water Rights: Both the CAST and NRC reports discuss the uncertainty hanging over western water rights due to unquantified Indian reserved water rights claims. The CAST report predicts the overall impact on western irrigated agriculture from quantification of Indian reserved water rights claims will likely be "quite small" because the measure of the Indian claims is the amount of water needed for "practicably irrigable" acreage. As a consequence, development of irrigated agriculture on tribal lands may simply offset land taken out of production off the reservation or, alternatively, tribes may sell or lease water to others off the reservation, the report notes.

On the other hand, treaty rights to instream flows for fishery resources, particularly in the Pacific Northwest, may "profoundly influence" the future of irrigation in this area, according to the NRC report.

IRRIGATION TECHNOLOGY: A PRIMER

Traditional irrigation techniques, such as flood and furrow irrigation, rely on gravity to deliver water to crops. With furrow irrigation, water is diverted from a ditch, or other water transport system, to flow down a furrow between rows of crops. With flood irrigation, water is similarly diverted but in a sheet of water over a slightly graded section of land between widely placed levies. Both methods require a substantial volume of water over a short period of time, according to the NRC report. To get water from one end of the field to the other, a farmer must use more water than is needed for plant consumption, Joe Goecke, president of Valmont Irrigation, an irrigation manufacturing company, noted at the EESI briefing.

Modern irrigation technologies, such as sprinkler and drip irrigation, use energy to pump water through closed systems to the crops. These technologies allow more frequent irrigation with smaller volumes of water, the NRC report notes. The distribution of water is more uniform than with gravity irrigation, less water is lost to evaporation, deep percolation and runoff, and soil erosion is reduced, according to the NRC report, Kimmell and Goecke. With more uniform and timely application of water, more crops can be produced with less water, according to the NRC report and Goecke.

State-of-the-Art Flood Irrigation: For more efficient flood irrigation, farmers can level their fields with the use of a laser leveler system to achieve a close to zero grade decline, Dale Bucks, national program leader for water quality and water management at the U.S. Department of Agriculture's Agricultural Research Service (ARS), noted at the EESI briefing. By means of a laser beam, a laser leveler system adjusts earth-moving machinery in the field to remove high spots and fill low spots. As a result, larger fields of a uniformly low grade can be irrigated with less water, according to Bucks.

A white powder flocculent, polyacrylamide, developed only recently by the ARS, can reduce sediment loss from flood irrigation by 95%, Bucks said.

State-of-the-Art Micro- and Sprinkler Irrigation: Pivot sprinklers have been around for about 40 years, according to Goecke. Today pivot sprinklers can use half the pressure and flow rates of earlier models, noted Kimmell.

Micro-irrigation, including drip, subsurface, bubbler and spray irrigation, delivers water to the soil through a network of tubing, according to the NRC report. Drip irrigation puts water at the root zone one drop at time, according to Kimmell. With a very low flow of water, the farmer can deliver just the right amount of water needed by the plant, he explained. Plastics have made drip irrigation possible - the drip device is less than the size of a dime and costs less than a dime, he said. It is a sophisticated technology in an inexpensive package, he noted.

Orchards, such as citrus and nut crops, have converted from "impact" sprinklers, which project water through the air, and from furrow irrigation to micro-sprays, thereby reducing both the amount of water used and the pressure needed to move water, Kimmell stated. As a consequence, less water and energy are consumed, he noted.

According to Kimmell, 4.5 million acre-feet is saved each year by the use of more sophisticated irrigation techniques, such as improved sprinklers and micro-drip systems. To put this in perspective, 4.5 million acre-feet equals the personal use of every man, woman and child in the 29 largest cities in the United States, he stated.

State-of-the-Art Computerized Technologies and Irrigation Scheduling: With solar-powered energy in the field, a farmer can sit at a computer in his office and manage water in fields 40 miles away, according to Kimmell. Automated irrigation can reduce labor and management costs, according to the CAST report.

Irrigation scheduling and automated canals provide new, more efficient ways to deliver water to the field, according to Bucks. About 10% to 15% of farmers use some form of irrigation scheduling, he said.

New technologies can help farmers apply the right amount of water to plants when they need it. Using satellite information, computerized technologies can show fields as wet or dry, said Bucks. Automated equipment can map saline conditions throughout a field, he stated. Computerized technologies can test the evapotranspiration of plants to determine more accurately when plants need to be watered, he said. Weather stations on a golf course or farm can read the micro-climate and adjust irrigation systems to apply water in just the right amounts, according to Kimmell.

Other technologies allow for more precise application of chemicals. For instance, with the aid of a small device, farmers can measure the nitrogen uptake by a plant and delay application of more fertilizer until necessary, according to Bucks.

Biotechnology: Biotechnology includes interspecies gene transplants, designer crops, and an array of new approaches to weed, pest and fertilizer management, according to the CAST report. Developments in biotechnology are likely to provide important means of adapting to constraints on water availability and use, it concludes.

WHAT ROLE CAN TECHNOLOGY PLAY IN MEETING THE CHALLENGES FACING IRRIGATORS?

"Growers have at hand numerous means of responding to change, and their willingness to invest in the development of new technology and new management regimes will enhance their adaptability," the CAST report states.

New technologies, allowing more precise water management and fully automated irrigation systems, will enable farmers to minimize water use and lower costs, the CAST report concludes. It also notes that biotechnology may develop crops that are pest and disease resistant or require less fertilizer or water.

Priorities for Future Irrigation Research: Future irrigation research should strive for a better understanding of the economies of scale regarding irrigation; develop further precision agricultural methods; improve the uniformity of water application; and develop better tools for applying water in an environmentally safe way, according to Bucks. Water application can be made safer for the environment by finding better ways to apply pesticides and fertilizers in just the right amounts, thereby avoiding over-application that impairs water quality, and by developing improved practices to reduce excessive runoff of water, he stated. Another priority for irrigation research is developing sensing techniques and remote operation of equipment for small farmers, he noted.

A priority for future irrigation research should include economic research on the costs and benefits to farmers of investing in irrigation scheduling and other irrigation equipment and practices, Wilford Gardner, chairman of the committee issuing the NRC report and dean and professor emeritus of the University of California at Berkeley's College of Natural Resources, noted at the EESI briefing.

Research on the future potential for using reclaimed water to irrigate agriculture and landscape turf should be a priority, according to Kimmell.

WHAT IS THE FEDERAL ROLE IN DEVELOPING **INNOVATIVE IRRIGATION TECHNOLOGIES AND PRACTICES?**

The availability of future innovations depends on the willingness of both the public and private sectors to invest in research and extension, states the CAST report. "Without such investment, many of the innovations needed to cope with the new realities of irrigated agriculture will fail to materialize. Indeed, the ease with which irrigated agriculture is able to adapt likely will be related directly to future levels of investment in agricultural research and development," the CAST report concludes.

Federal Research: While advances in innovative irrigation technology are necessary for agriculture to adapt to changing demands and changing supplies, investment in irrigation research at federal and state levels is dramatically dropping, according to Gardner. "[L]evels of both federal and state investment in agricultural research and development are falling in real terms, and the outlook suggests further declines," the CAST report concurs.

As a consequence, the private sector must play a larger role in research and even greater role in dissemination of information and technology to the farmer, Gardner noted.

"Rates of both private and public investment in agricultural research and development in the United States are below those in other developed countries. Failure to invest in the research needed to maintain U.S. agriculture's position as the most productive in the world will complicate greatly the challenge of adapting to the change confronting western agriculture," the CAST report states.

Basic Research: To help farmers adjust to the challenges facing irrigated agriculture, the CAST report recommends that federal policies provide for and underwrite public investment in basic research and "other research yielding benefits that cannot be appropriated exclusively by individual growers."

While the irrigation industry can refine a product for market and disseminate information to farmers, it is not set up to do basic research, according to Kimmell.

Private Research: "Public policies encouraging private investment in agricultural research and development could be very important to helping agriculture adapt to change," the CAST report concludes.

Partnerships: With continuing pressure to reduce federal expenditures, more leadership and funding for research and development must come from the private sector and through partnerships between irrigators, the private sector, and state and federal researchers, according to the NRC report.

The ARS has been working with the U.S. Department of Agriculture's Natural Resources Conservation Service, the Irrigation Association and others to develop databases to show improved irrigation practices do a better job of managing water, Bucks reported. The ARS also has been working with the irrigation industry in a collaborative effort to develop a list of research needs, he said.

While the U.S. Department of Agriculture and the irrigation industry are already working together to cooperate on research, farmers need to be brought more effectively into the process, said Kimmell.

Pivot irrigation was invented by private industry, but the refinements and education of users came from the entire scientific infrastructure that supports agriculture in the United States, noted Goecke, referring to the federal, state and academic institutional support for research, development and information dissemination.

Copies of the NRC report may be obtained from the National Academy Press, (202) 334-3313, (800) 624-6242. Copies of the CAST report may be obtained from CAST, 4420 West Lincoln Way, Ames, IA 50014-3447, (515) 292-2125.

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