CSREES AGRICULTURAL WATER SECURITY WHITE PAPER

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Executive Summary

Agricultural water security will move us towards the realization of a ***sustainable water use scenario***— by maximizing the efficiency of water use by farmers, ranchers, rural and urbanizing communities, thus ensuring water volumes allocated for per capita domestic water consumption, ecosystem services, recreation and aesthetics while meeting the needs of food and fiber production. This paper describes an Agricultural Water Security Initiative to create and enhance research, education, and extension programs funded by the Cooperative State Research, Education, and Extension Service (CSREES). The Initiative puts into action bold steps identified at the USDA Research, Education, and Economics mission area listening session on agricultural water security. Three promising areas for CSREES research, education and extension programs are:

- Exploring new technologies for the use of recycled water and water conservation in agricultural, rural, and urbanizing watersheds;
- Probing the human, social, and economic dimensions of agricultural water security with a focus on adoption-outreach; and
- Researching biotechnological improvements in water use efficiency of crop and horticultural plants to yield greater "crop per drop."

We explore opportunities for new partnerships with other federal agencies, private and non-profit groups in this Initiative and strengthen the partnership between USDA-CSREES and the land grant universities.

Overview

For years, finding enough water for people meant finding more water to use. Today, and into the future, we need to find ways to use water in a more sustainable manner through a paradigm shift that stresses increased water use efficiency across all sectors. Agriculture, as the single greatest water consumer in the world and controlling the greatest volumes in the United States, has a unique, mandated responsibility to manage in a sustainable manner national and global water resources. The U.S. Department of Agriculture (USDA) is positioned to provide leadership (USDA, 2002) …"on food, agriculture, natural resources, and related issues based on sound public policy, the best available science, and efficient management."

In September 2004, the USDA Research, Education, and Economics (REE) mission area hosted a listening session aimed at identifying strengths, knowledge gaps, challenges, and opportunities for a USDA response to agricultural water security (Dobrowolski and O'Neill, 2005). Participants in this listening session identified bold steps for USDA to take that would help achieve a sustainable water scenario through the year 2025. Participants in the listening session also identified appropriate federal, state, and local partners that must be engaged in these bold steps to insure success.

USDA's Cooperative State Research, Education, and Extension Service (CSREES), the Federal partner with land grant universities nationwide, is uniquely positioned to establish a new *Agricultural Water Security (AWS) Initiative* supporting and coordinating research, education, and extension programs across the country to avoid crisis and conflict over water. This Initiative would bring together cutting edge research and innovative education and outreach to focus on critical gaps in addressing water supply, availability, and distribution issues. These gaps involve irrigation efficiency and management linked to water marketing, drought preparedness, rural/urban water reuse technologies and adoption, extending agricultural water conservation strategies to the urban sector, and developing water-relevant biotechnologies (Dobrowolski and O'Neill, 2005). Immediate action could be taken through the Cooperative Extension System (CES), reaching across the country with county-based programs that promote behavioral change at the individual and community level, supported by applied research from the Land Grant University System to champion greater water use efficiencies. The AWS Initiative would use a holistic, watershed/aquifer-based approach to issues in water supply, allocation, and distribution taking advantage of CSREES' unique relationship with the existing infrastructure of the university system and the diversity of its research, education and extension missions.

The following concepts define the proposed Agricultural Water Security (AWS) Initiative:

- We need to better understand the future of irrigated agriculture in the Nation, including alternatives to irrigated agriculture for a safe, dependable food supply and determining how future climate change and population growth scenarios could affect water supplies and water demands. How will our Nation's agricultural industry respond to increasing competition from other countries?
- We need to develop new science and technology focused on widening the array of choices for conserving water. This new science should evaluate how knowledge, incentives, and policies help to promote appropriate decision-making. Ultimately, we

need to find ways to help agricultural water districts identify and cope with change such as urbanization and competition for water.

- We need to extend and expand current paradigms for water education and extension/outreach. How can education play a role to cultivate effective water management and water policy from the individual to the community and the global level? This new paradigm should explore new strategies to understand behavioral change and how social and economic factors affect decision-making for water resources management.

Do we have an agricultural water security problem?

Water is critical to maintaining human health and well-being, protecting and sustaining sensitive ecosystems, producing food and fiber into the future, enhancing recreation and aesthetics, and providing for the long-term security of people and nations. Providing enough water to meet human demands across the nation is challenging water policy makers—due primarily to water being viewed as a human entitlement, delivered below cost and used inefficiently. Of the 147 countries ranked for water efficiency by the World Water Council, the United States ranked last where inefficiencies at times reach 50% (NCSE, 2004).

Globally, farmers are irrigating five times more land than at the beginning of the 20th century. Withdrawals for agriculture doubled and domestic and industrial uses quadrupled between 1950 and 1995. In the U.S., growing populations and changing values have increased demands on water supplies and watersheds, resulting in water use and management conflicts, particularly in the western U.S. where populations are expected to increase 30% in the next 25 years. Across the country, agricultural needs are often in direct conflict with urban needs and with demands to sustain or improve ecosystem services, recreation, and tourism. Water issues being debated include enhancing supplies with new storage facilities, expanding existing infrastructure, funding for water reclamation and reuse, and lowering water consumption. The U.S. Department of Interior (DOI) responded to this changing global scenario by introducing *Water 2025*, an initiative led by the Bureau of Reclamation (BOR), aimed at avoiding conflict arising from water crises in the western United States through improved technology and management of water resources (www.doi.gov/**water2025**/). Congress considered water resources management important enough to deliberate title transfer and wastewater reclamation and reuse bills, Indian water rights settlement bills, and the reauthorization of large-scale watershed management and restoration programs – all with program elements inexorably linked to agriculture and USDA — during the 108th Congress (Cody and Sheikh, 2005). The 109th Congress is likely to consider and reconsider issues surrounding water resources management spanning the transfer of title of federal storage and conveyance facilities to project users, water project authorizations, agency policy changes dealing with oversight and sustainability (e.g., Klamath Basin, Salton Sea), broader evaluations of federal water activities that include research and development, education, and the establishment of a national water policy commission. USDA-CSREES will be prepared to work with partner agencies and institutions to help address these congressional needs through implementation of the AWS Initiative.

Meeting the basic needs of humans and the environment will require fundamental changes in the approach to water management and use. Three scenarios for the future of agricultural water security are envisioned – a "business as usual" scenario, a "water crisis" scenario, and a "sustainable water use" scenario (Rosegrant et al., 2002).

Business as usual trends to 2025 in water resource management, policy and investment suggest declining outlays for expanding surface water irrigation systems and reservoir storage in the face of greater demands for food and fiber crops, thereby promoting increased import requirements. Without sufficient surface sources, farmers will depend more on frequently overused aquifers. Greater consumption of water for non-irrigation uses (+62%), especially domestic uses (+70%), to 2025 by developing countries will increase water scarcity and conflict. By contrast, developed countries through initiatives like Agricultural Water Security could experience lower per capita domestic water use where the highest per capita consumption takes place.

Under a ***water crisis scenario***—persistent drought, continued global climate change, rapid demand changes, moderate worsening of water policy and investment—governments further cut water infrastructure investments, transferring irrigation systems to users without necessary reforms in water rights. Failing public infrastructure forces irrigation prices to rise with falling water use efficiency. Irrigators fight price increases resulting in conflict at the local level and failed management at the watershed level. Water reserved for ecosystem services will be the subject of unregulated and illegal withdrawals. Key aquifers will fail due to unsustainable extraction leading to widespread farm failure. Growing urban centers will demand greater water volumes from newly privatized water and sanitation firms who will cater to people who can pay—while per capita consumption drops as accessibility tightens.

Securing adequate water supplies to meet the food and fiber needs of an expanding population and maximizing the efficiency of water use by farmers, ranchers, and rural and urbanizing communities is the goal of CSREES's *Agricultural Water Security Initiative*. This Initiative will move us towards the realization of a ***sustainable water use scenario***—greater water volumes available for domestic water consumption and ecosystem services while maintaining food and fiber production at "business as usual" levels. Sustainable water use would achieve greater social equity and environmental protection by careful reform in water management through sound government and private sector action.

Agricultural Water Security needs to address national issues in an integrated manner with a focus on programs rather than projects, solving problems at multiple scales. Research, education, and outreach needs to be coordinated across government with the resulting knowledge and technologies focused on assisting water managers and water policy decision makers (Engberg, 2005).

Considerable scientific information exists regarding the efficient use of water for agricultural irrigation. Similarly, much is known about the impacts of drought on plant growth and productivity (see Clemmens and Allen, 2005). However, there is a need to expand the knowledge base of Agricultural Water Security through research, education, and outreach programs aimed at (see Dobrowolski and O'Neill, 2005):

- Risk assessment associated with drought and water shortage and links to global change.

- Risk management for farmers, ranchers, rural residents, and urbanizing communities facing impacts of drought and water scarcity.
- Sociological and economic impacts linked to the adoption and acceptance of water supply and conservation technology.
- Better indicators and methodologies to assess the value of environmental services, value and costs of environmental degradation, and impacts of water and crop subsidies.
- Better quantification of the environmental water needs to achieve sustainable ecosystem services, and recognition of expanding water needs for recreational uses.
- The role of physical and paper water banks, progressive rate structures and other market-based or incentive mechanisms; quantifying the full cost of providing water to different use and quality classes.
- Development of drought tolerant, poor soil and water quality tolerant plant species for agriculture and rural and urban landscaping.
- Impacts of water conservation and reuse on downstream water supplies – addressing upstream efficiency and the potential for decreased downstream supply. What are the public health and environmental concerns of reused water? How can agriculture treat or improve return flows?
- Databases that are composed of spatial water resource data used for agriculture to assess current demands and use and predicting areas of concern and water resource data that affects the maintenance and improvement of ecosystem services.
- Tools for integrated decision making including forecasting supply and shortage.

Current activities in CSREES

The role of CSREES within the REE mission area of USDA is to provide federal assistance for research, education, and extension/outreach in support of five strategic goals. Providing leadership to the AWS Initiative is appropriate for CSREES because it fills a distinctive niche among federal agencies and it is uniquely positioned to mobilize the capacity of the land grant university system and other research and education organizations across the nation.

Land grant universities have a long history of research, education, and extension efforts aimed at water resources management supported in part through formula funding provided by the Smith-Lever and the Hatch Act. These projects, including the multi-state projects funded through the Hatch Act, have focused on water availability, water management and economics, as well as plant responses to environmental stresses such as drought.

CSREES also has administered a number of competitive grants programs in the National Research Initiative (NRI), the Small Business Innovation Research program, and the National Integrated Water Quality Program (NIWQP) that address AWS issues. The NRI Watershed Processes and Water Resources Program has focused mostly on water quality issues but also has addressed hydrology of agricultural and rural watersheds. Plant stresses caused by drought, salinity, and flooding are priority areas for the NRI Agricultural Plants and Environmental Adaptation Program. The Small

Business Innovation Research (SBIR) Program successfully promotes technology development that leads to water conservation. Much of the focus of SBIR's efforts has dealt with development of irrigation technologies for agricultural water conservation. Since 2000, the NIWQP has addressed water resource issues in agricultural, rural, and urbanizing watersheds. However, in FY 2005 the NIWQP emphasized *measurable behavior change* to reflect the greater emphasis on actual adoption of new technologies and stakeholder behavioral change. This reflects a major shift in emphasis that challenged the research and education community to explore social and economic factors that impact water quality and quantity management decisions. Measurable behavior change requires the design and testing of tools to assess changes in the adoption of new water-saving technologies and water consumption. These new outreach efforts should make use of new information delivery mechanisms such as those developed through eXtension (http://intranet.extension.org).

How do we move AWS ahead with our federal partners?

It is imperative that CSREES design strategies with appropriate outcomes and assessments that dovetail with the Administration's national research and development priorities and reflect the specific mission of USDA and CSREES. Marburger and Bolten (2005, p.5) clearly state the federal research and development priorities:

> "The ability to measure, monitor, and forecast U.S. and global supplies of fresh water is important because agencies are developing a coordinated multi-year plan through NSTC to improve research to understand the processes that control water availability and quality, and to collect and make available the data needed to ensure adequate water supply for the future."

Ongoing efforts within USDA

Coordination of water resources research and education takes place through three existing activities within USDA – the USDA Working Group on Water Resources, the USDA Drought Coordinating Committee and USDA Drought Team, and the Partnership Management Team (Phills, 2005). These three forums bring together agencies from across all USDA mission areas and create opportunities for USDA to establish or strengthen partnerships focused on water resources issues (Figure 1). The primary USDA agencies involved in these activities are:

- Agricultural Research Service (ARS),
- Cooperative State Research, Education and Extension Service (CSREES),
- Economic Research Service (ERS),
- National Agricultural Statistical Service (NASS),
- Risk Management Agency (RMA),
- U.S. Forest Service (USFS),
- Natural Resources Conservation Service (NRCS),
- Farm Services Agency (FSA), and
- Rural Utilities Service (RUS).

We present three existing and potential partnerships that exemplify opportunities for coordination within USDA. The three examples include an ongoing partnership

among NRCS, ARS, and CSREES on the Conservation Effects Assessment Project (CEAP) and potential partnerships between CSREES and USFS, and between CSREES and RMA.

The CEAP partnership was initiated in 2003 in response to calls for improved accountability for conservation programs within USDA. ARS and CSREES joined NRCS in an effort to provide research-based information on the effects of conservation practices on water quality at the watershed scale. CSREES' unique contribution was to include evaluation of economic and social considerations in management decisions and how these considerations ultimately impacted water quality. CSREES also required projects to include an outreach-education component where farmers and ranchers received knowledge on the effects of conservation practices in their watershed. There is a clear opportunity to expand the existing CSREES-NRCS partnership on CEAP to address issues related to the AWS initiative.

Since the late 1990's, the USFS has dealt with educational/behavioral change and conflict resolution issues associated with water use on federal lands (Hodgson 1991, Rey, 2005). With an extensive network of social scientists and economists across the U.S., a partnership involving CSREES and USFS could provide needed assistance with the evaluation of adoption-outreach and behavior change focused on all aspects of water availability. This area offers a promising opportunity for CSREES to establish a joint research, education, and extension/outreach program focused on social and behavioral issues associated with water resources management involving CSREES and the USFS.

Payments from the USDA RMA to agricultural producers affected by drought have reached record amounts in the last decade. An opportunity exists for CSREES to partner with RMA to improve our understanding of agricultural risk associated with drought and to develop cost effective strategies to assist farmers and ranchers dealing with drought. It is possible that a joint competitive grants program could be established between CSREES and RMA focused on improving the characterization of risk and development of improved risk-based tools to address drought.

Ongoing efforts with other federal agencies

Federal water agencies across government are on notice to improve the water resources research enterprise, to minimize duplication, to provide a sound basis for decisions about the allocation of funds and scope of research, to provide a coherent strategy to Congress and the people of the United States for federal investment, and to insure that large-scale, multi-agency efforts are advanced to solve impending water issues (NRC, 2004; NSTC, 2004). CSREES, in cooperation with federal partners, should focus research, education, and technology on needed improvements toward a goal of a safe and sustainable water supply in the United States to meet human and ecosystem demands. Our partners across government (Table 1) are best represented by the Subcommittee on Water Availability and Quality (SWAQ) of the Committee on the Environment and Natural Resources (CENR) of the National Science and Technology Council (NSTC). SWAQ was established in 2002 to advise and assist the CENR and NSTC on policies, procedures, plans, issues, scientific developments, and research needs related to the availability and quality of water resources in the United States.

At the federal level, CSREES coordinates research and education programs with other federal agencies through the CENR SWAQ. As part of its mission, this committee provides a forum for coordination of research and education programs that span more than 15 federal agencies. This subcommittee recently completed a publication focused on water availability in the United States (NSTC, 2004).

TABLE 1. Membership on the Committee on Environment and Natural Resources, Subcommittee on Water Availability and Quality

Executive Office of the President
- Council on Environmental Quality
- Office of Management and Budget
- Office of Science and Technology Policy

National Aeronautics and Space Administration
National Science Foundation
U.S. Department of Agriculture
- Agricultural Research Service
- Cooperative State Research, Education, and Extension Service
- Forest Service
- Natural Resource Conservation Service

U.S. Department of Commerce
- National Oceanic and Atmospheric Administration

U.S. Department of Defense
- Army Corps of Engineers

U.S. Department of Energy
U.S. Department of the Interior
- Bureau of Reclamation
- U.S. Geological Service
- Fish and Wildlife Service
- National Park Service

The AWS Initiative provides an excellent opportunity for CSREES and the land grant partnership to engage BOR with Water 2025 and other federal agencies in meeting the nation's water resources challenges. CSREES is strategically positioned to work with land grant universities to address social, economic, and behavioral issues of agricultural water security. These social and economic questions are at the core of decision-making, and understanding these issues ultimately may lead to greater water use efficiency in agricultural, rural, and urbanizing watersheds. CSREES could explore opportunities to partner with BOR to create a joint competitive grant program aimed at providing research and education activities needed to fully realize the potential of Water 2025.

How do we involve non-federal partners?

CSREES must include other partners such as river basin commissions and national and state level non-governmental organizations (NGOs) with water as a focus, for example: Water Environment Research Foundation (WERF), Water Education Foundations, WateReuse Foundation, American Water Works Association (AWWA), American Water Resources Association (AWRA), American Geophysical Union (AGU), The Nature Conservancy (TNC), National Institutes of Water Resources (NIWR), Universities Council on Water Resources (UCOWR), and others. These groups have extensive histories of working on water resource issues and also providing educational materials to a wide array of audiences. CSREES through the 106 land grant universities can engage these other organizations to achieve key objectives of the AWS Initiative. Opportunities should include jointly sponsored workshops, targeted symposia at national meetings, and coordination of educational materials for water resource management.

The CSREES AWS strategy

Meeting our water availability challenges through 2025 and beyond compels us to develop bold steps to redirect our current, mission-driven agendas. Six themes for research, education, and extension activities were identified at the REE listening session (Dobrowolski and O'Neill 2005). The six themes are: Irrigation Efficiency and Management; Drought Risk Assessment and Preparedness; General Water Conservation and Management; Rural/Urban Water Reuse; Water Marketing, Distribution and Allocation; and Biotechnology. From this list of six themes, ARS is committed to continuing support for irrigation technology. The National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln has a continuing mission to develop tools and provide education for drought preparedness. Finally, there is a broad interagency effort (SWAQ) to improve water conservation at the watershed scale.

CSREES should focus on the three remaining themes that appear to offer the greatest promise for near-term gains in agricultural water security:

- Exploring new technologies and systems for the use of recycled/reuse water in agricultural, rural, and urbanizing watersheds,
- Probing the human, social, and economic dimensions of agricultural water security (including water markets) with a focus on adoption-outreach and behavioral change, and
- Discovering biotechnological improvements in water use efficiency of crop and horticultural plants to achieve greater "crop per drop."

These three themes from the participant-led AWS listening session fit within the research and education challenges (water availability, quantity and quality; water use; and water institutions) described by the National Research Council (2001, 2004) and supported by the Administration (OSTP 2004).

Figure 2 is a flow diagram which illustrates the sustainable water use scenario by depicting positive flows (research, education, and program and policy development) against negative flows (the status quo and limited resources) for an AWS Initiative.

Promising areas of research, education, and extension

The three promising areas of research, education, and extension/outreach for CSREES are outlined here and key questions are identified. We anticipate that additional questions will be developed as these areas are further developed.

1. Expand the NRI program for Agricultural Plants and Environmental Adaptation to conduct basic research to improve biotechnological tools that alter the metabolism of plants to adapt to water stress (including drought, salt, and flooding stress). The success of this research will depend in part upon the public perception of transgenic organisms and genetic engineering. Along with research, appropriate outreach and education efforts are needed to bring together scientific advances and public acceptance. Important research, education, and extension questions are:
   - Can germplasm collection of tolerant genotypes be used as a source of new genes for agricultural and landscaping plants?
   - Can these tolerant genotypes be developed by genetic engineering or other techniques?
   - Can novel molecular and biotechnological methodologies be developed to identify and characterize stress-related genes to use as probes for selection of tolerant genotypes and for generation of transgenic plants?
   - What functional genomic studies are needed to analyze function and interaction of genes important for tolerance to environmental stresses?
   - What tools and strategies are needed to insure that public perception of transgenic plants is based upon scientific knowledge? How do we promote appropriate use of transgenic organisms and genetic engineering for the public good?
   - How can training in plant breeding and germplasm enhancement be improved or expanded to insure a future generation of plant breeders?

Potential federal partners for this activity include ARS and the National Science Foundation (NSF). Coordination of research, education, and extension agendas will be critical to insure that the maximum benefit is gained from this program.

2. Create an Integrated Program for AWS that addresses water reuse, conservation and wastewater reuse for agricultural, rural, and urbanizing watersheds. Water reuse is a rapidly evolving water-management tool for supplementing limited water resources around the globe. Research and education/outreach are important to foster the development of criteria and standards for economical and sustainable solutions that will help protect public health and the environment. Research is needed into new and emerging treatment and reuse technologies, such as membrane bioreactors. Further research needs to be done on the socioeconomic impacts of reuse projects – considering the tangible and intangible economic return to offset the elevated capital and operating costs. Key questions include:
   - How do we evaluate and improve risk assessment and risk management approaches for wastewater irrigation in terms of public health and pollution?

- What strategies or tools can be developed for effective education and outreach related to water and wastewater reuse for producers, for decision-makers, and for the public?
- How can the risks and benefits of nutrients and contaminants from wastewater be assessed and managed? What risks and benefits exist for soil quality?
- What sustainable practices are being used that can be transferred to benefit other rural areas in the U.S. and in other countries?
- From a public health perspective, which crops are the best candidates for wastewater irrigation and which should be avoided?

Several key federal partners could be engaged in this effort including ARS, BOR, U.S. Army Corps of Engineers (COE) and U.S. Environmental Protection Agency (EPA) Office of Wastewater Management and Office of Water, especially when considering investment in urban/rural water reuse and associated educational activities (U.S. EPA 1991, 1992).

3. Develop an extension-led integrated program for "*adoption-outreach*" of water technologies – achieving true behavioral change among farmers, ranchers, and citizens where the full value of water is appreciated, and the risks to water supplies from mismanagement, population growth and changing weather patterns are understood. There are often large discrepancies between the risks experts worry about (e.g., a global water crisis) and those that lay people are most concerned about. The perception of a given risk is amplified by what psychologists call "outrage factors," which can make people feel that even small risks are unacceptable (Hallman et al. 1995). Bringing USDA technology and know-how into the urban, urbanizing, and rural residential environment will require a new paradigm for Cooperative Extension professionals similar to the model implemented by food science researchers and extension educators to counteract obesity. Results should help to provide water managers and policy makers with options and tools that lead to behavioral change and a reduction in social conflict. Important research, education, and extension questions include:
   - How do we design tools to evaluate adoption-outreach outcomes or performance-based measures of outcome?
   - What applied research or technology is needed to overcome knowledge gaps that constrain adoption-outreach of water conservation and reuse?
   - What are the socio-economic drivers of behavior change? How do we best evaluate the linearity and non-linearity of science and social feedback loops related to behavior change?
   - How do we overcome the mismatches that exist between actual and perceived risk of water availability or water-borne hazards?

Potential federal partners for outreach-adoption include USFS Research, ERS, EPA, and the U.S. Department of Education (USDOE).

Key to implementation of the USDA CSREES AWS Initiative is a need to strengthen socio-economic dimensions of water reuse and adoption-outreach across the agency. CSREES must engage a National Program Leader (NPL) in the human

dimensions of natural resources and environmental management. This NPL should specialize in understanding divergent societal values, economic forces, changing demographics, and resource sustainability that increase the number and complexity of natural resource management conflicts. USDA and CSREES need greater knowledge of attitudes, motivations and values that motivate individuals and communities to conserve natural resources. Significant progress on the pathway to sustainability is dependent on understanding human motivations, values and behaviors in relation to natural resources management, especially water. Existing programs (formula and competitive) would be enhanced through the inclusion of socio-economic sciences, and a new competitive program could serve a variety of natural resource management challenges. The narrow and incomplete economic valuations and forecasts we currently use are inadequate for making sound management decisions. Often management decisions are based on cost-benefit analyses that undervalue our natural resources (Young, 2005). We are in the very early stages of being able to value water and other natural resources in a comprehensive manner that includes ecosystem services and recreational values. We need to improve our valuation capability – focusing solely on the economics of commercial activities ignores the full value of natural resources and ecosystem services they provide to society.

How can we evaluate the impact of AWS?

Agricultural water security is an integral part of Goal 5 – "*Protect and Enhance the Nation's Natural Resource Base and Environment*" – in the USDA Strategic Plan. Impacts of water use efficiency, expanded water availability, and healthier aquatic and estuarine ecosystems are part of the current and future accountability measures associated with this goal.

Crop technologies that reduce the need for irrigated agriculture in arid environments, provide greater agricultural production under poor soil and water quality regimes, and concomitantly provide for expanded economic growth are indicators of success. Increasing available water for sustaining natural ecosystems would signal sustainability in water use – greater irrigation return flows surveyed by NASS, could be used as a surrogate for such a measure of sustainability.

An improvement in knowledge, attitudes and behavior relative to water use conservation and water reuse would also mark positive progress. Therefore, measures of adoption of conservation and water reuse practices can demonstrate progress in relation to agricultural water security.

At the individual level, success measures might include per capita water use estimates for various states, regions, and the nation. Increases in the volume of reuse water delivered to the household and farm level is an indicator of success. CSREES could monitor the development, marketing and application of reuse technologies by evaluating changes in the market share of raw water and treated water technologies. At the community level, measures of success might include the increase in population served by a surface or ground water supply, community sustainability, or the value of water "saved" through various conservation measures.

Changes in community involvement in water quality and quantity related issues and changes in public policies that impact opportunity for healthier and sustainable water supplies would also indicate positive progress. Data from national surveys, the

water quality evaluation and reporting system, CSREES supported evaluation studies, and feedback from CSREES supported state Cooperative Extension programs can be used to identify the most successful strategies for addressing/averting the next water crisis.

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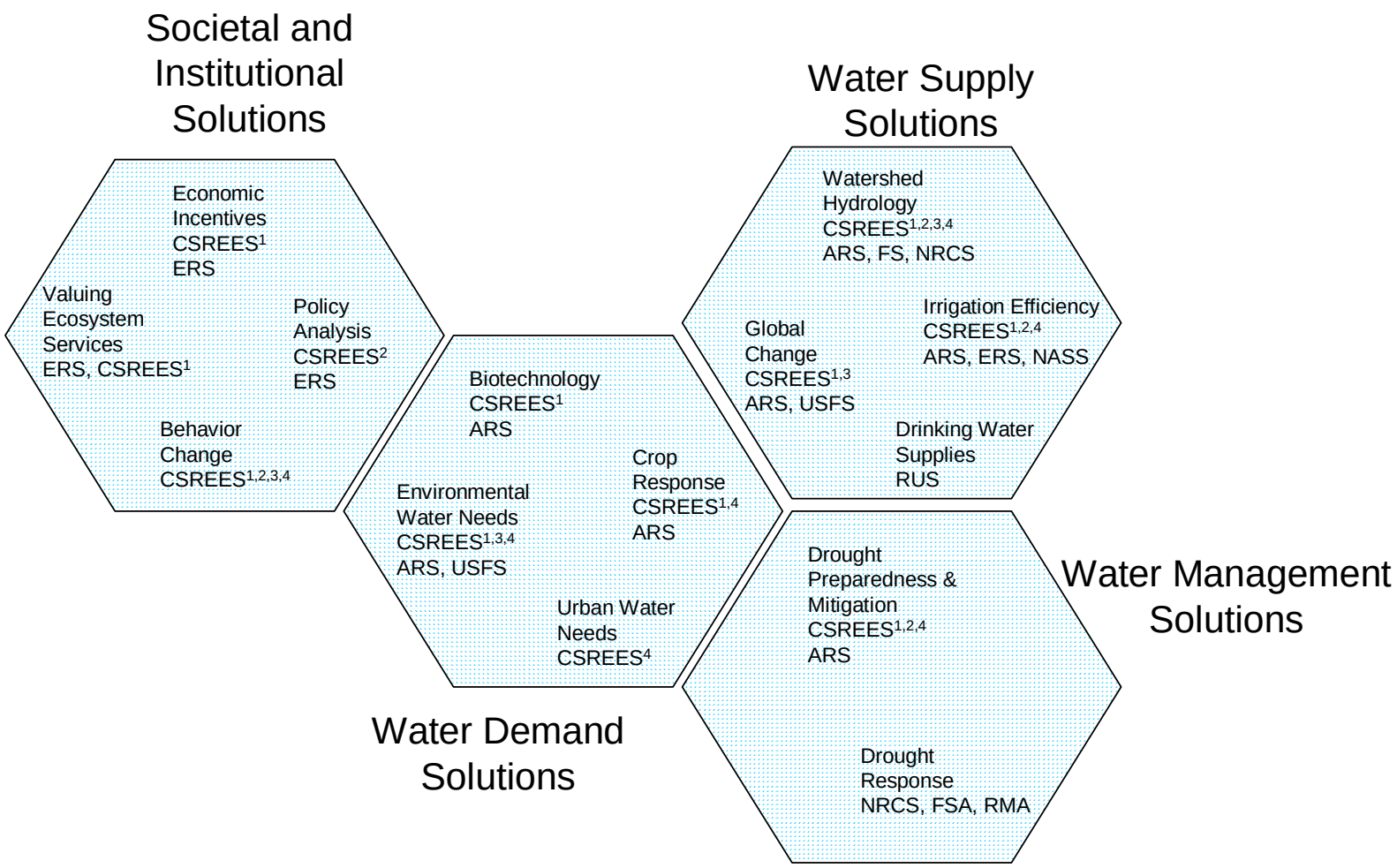
Figure 1. USDA AGRICULTURAL WATER SECURITY EFFORTS



[1]CSREES Research, [2]CSREES Integrated, [3]CSREES Education, [4]CSREES Extension

Figure 2. RESEARCH, EDUCATION, AND OUTREACH IN SUPPORT OF SUSTAINABLE WATER RESOURCES MANAGEMENT