

Colorado State University

COLLEGE OF AGRICULTURAL SCIENCES

21st Century Solutions for Food Systems and the Environment



Strategic Initiatives Executive Summary

21st Century Solutions for Food Systems and the Environment

A proposal for strategic investments in the College of Agricultural Sciences at CSU

The College of Agricultural Sciences will enhance and expand programs fundamental to food production and safety, develop technologies and techniques that best utilize limited resources, and conserve our natural resources for sustained production for an ever increasing global population. Our programs will interface with other disciplines across the CSU campus and with other universities and laboratories nationally and internationally to attract large-scale competitive funding to support research, education, and outreach endeavors and to upgrade facilities and equipment. Thus, it is imperative that our people and programs are highly visible—communicating a clear and concise vision for the college and educating decision makers about Colorado State’s capacity to address critical 21st Century issues.

We have built upon our 2005 strategic plan, a plan that identified base programs that are critical to addressing the educational and research mission of the College. From this strategic plan we have developed five targeted programs, or strategic initiatives, for strategic investments to enhance the impact and visibility of our research, education, and outreach efforts. The initiatives build on the strengths of the College of Agricultural Sciences. These initiatives were developed in concert with national (USDA NIFA and others) and state (Colorado Department of Agriculture) priorities for agriculture and the food system to ensure that our vision for future programmatic efforts is in line with the priorities of Colorado and the U.S.

Implementation Considerations

Implementation of each of these initiatives is critical in addressing the social and economic challenges in maintaining and sustaining a viable and profitable food system in Colorado and throughout the U.S. These initiatives fall under the broader focus areas of the **Food System, the Environment, and Curricular Innovations**. The food system and the environment are intimately linked, thus efforts must be placed in both arenas to advance agriculture and secure its sustainability. This becomes the guiding focus of the College of Agricultural Sciences. A strong infrastructure is critical to implementing our high priority initiatives. The following are key components of our long-term CAS strategic plan.

- Enhance undergraduate and graduate education.
- Attract external resources to support our programs with an emphasis on multi-disciplinary approaches.
- Evaluate all faculty vacancies to determine the need to reallocate and support the strategic initiatives.
- Continue to support critical base programs not directly associated with a Strategic Initiative.
- Renovate facilities, acquire state-of-the-art equipment, and hire staff to adequately support faculty efforts. Renovation of Animal Sciences and Shepardson and construction of Ag Science research building are highest facility priorities.
- Improve communication with the public so that the impact of our programs is more visible and better understood.
- Provide professional development and recognition for faculty and staff.

The overarching focal areas for our programs in the College of Agricultural Sciences are the **Food System, the Environment, and Curricular Innovations**. Following are brief descriptions of our strategic initiatives within these areas.

A. Enhancing Our Food System

1. Assuring Food Safety and Quality

Assuring high quality, safe food for the domestic and international markets is of paramount importance. Additionally, new technologies that improve product quality and are consistent with evolving food safety practices must be developed. Education of consumers and other stakeholders must occur to prevent barriers to trade that might develop if new technologies are regarded as unacceptable. The Center for Meat Safety and Quality and the Food Safety Cluster of the Infectious Disease Supercluster are CSU anchor programs that strengthen this initiative. The specific objectives of this initiative are to develop research programs in muscle/lipid biochemistry, post-mortem metabolism, and food virology; enhance the current Center for Meat Safety and Quality; and implement a five-year BS/MS program in Meat Science/Food Safety.

Anticipated impacts resulting from this initiative include:

1. Laboratory techniques for protein separation and analysis, lipid metabolism and fatty acid composition, muscle and lipid growth and development, and diagnostics
2. A better understanding of viral etiological causes of food contamination and improved detection of infectious viruses
3. Improved means to control and facilitate elimination of viruses in foods
4. Cost/benefit analyses of emerging and future food safety technologies and systems
5. More CSU alumni that will be active in food safety programs throughout the world

2. Improving Food for Enhanced Human Health

This initiative encompasses a new transdisciplinary approach to improving food to enhance health via chronic disease prevention. CSU, with its branded, Crops for Health™ program, is a leader in this emerging field of study termed Biomedical Agriculture. The ultimate goal of this program is to reduce chronic diseases, i.e., obesity, diabetes, heart disease, and cancer, via food as the vehicle of choice for delivering health promoting chemicals to humans. Colorado State's competitive advantage includes crop breeding and improvement; molecular genetics and the health-related functional properties of crop metabolites; a strong Specialty Crops program; the Animal Cancer Center; the Cancer Prevention Laboratory; the School of Public Health; and consumer behavior and nutrition education expertise.

Anticipated impacts resulting from this initiative include:

1. Prescriptive diets, e.g. the Colorado Cuisine Modular Diet, with modules credentialed for specific crop varieties and endorsed by appropriate national public health organizations
2. New varieties of dry beans, potatoes and/or wheat that add value for Colorado crop producers based on their disease prevention abilities
3. A new graduate program in Biomedical Agriculture
4. Reduced rates of chronic disease incidence via better food

3. Developing Profitable and Environmentally Sound Beef/Dairy Production Systems

Colorado's beef and dairy industries generate \$4 billion in revenues annually. The goal of this initiative is to produce and optimize profitable and sustainable beef/dairy systems that will address the global challenges of hunger and health and minimize environmental concerns. Anchor programs that contribute significant multidisciplinary approaches to this initiative include the CSU Beef Team, Integrated Resource Management (IRM) Program, and the Institute for Livestock and the Environment (ILE). Scientists in these programs collectively address beef and dairy production systems, land conservation, environment, energy production, and management of invasive plant species.

Anticipated impacts resulting from this initiative include:

1. Strategies to increase feed efficiency and profitability in beef cattle
2. Management strategies in dairy cattle to reduce environmental impact
3. Management strategies in beef cattle to reduce environmental impact and more efficient use of resources
4. Increased demand for CSU faculty to serve as science-based advisors for environmental policy development

B. Enhancing Our Environment

4. Developing Land Use Strategies for Sustainable Agricultural and Urban Environments

Land use tradeoffs due to urban expansion will greatly impact the ability of agriculture to address hunger, alternative energy development, climate change, and environmental and economic sustainability. The initiative undertakes research and education in the design, modeling, and policy decisions surrounding land use in Colorado. In order to take full advantage of the expertise that exists at CSU we propose the development of a **Center for Land Use Analysis** that will focus on Colorado agriculture, regional economics and policy.

Anticipated impacts resulting from this initiative include:

1. Landscape design systems that improve interactions between wildlife and livestock and wildlife and humans as urban populations expand
2. Management solutions for invasive species in both managed and native ecosystems
3. Planning approaches that enable rural and urban communities to work towards common solutions to competing land and water resource needs
4. Increased economic benefit from agritourism
5. New models for best use of land resources based upon soil, climate, water, and competing needs
6. Designs for efficient water and land use in rural and urban settings

5. Optimizing Agriculture's Water Footprint

A major part of Colorado's arable land lies in the Great Plains, where plant production is limited by water. A critical aspect of water management in Colorado is coping with the competing demands for available water. The goal of this initiative is to use our combined strengths in the plant, animal, soil, and water sciences to address management of limited water resources in the state, nation, and throughout the world. By focusing on this goal, the initiative addresses the closely linked global challenges of hunger, health, and climate change. We intend to establish and model water footprints of important Colorado agricultural systems and, through fundamental and applied interdisciplinary research, develop and transfer more water efficient production technologies. This proposal emphasizes undergraduate

education in agricultural water management. We will create the Water Optimization Center to focus on management of mixed crop and livestock systems in limited water environments aimed at regional and international audiences.

Anticipated impacts from this initiative include:

1. Increased education of water managers and users resulting in improved water use efficiency
2. Integrated research in plant drought stress physiology and plant breeding/genetics resulting in increased planting of drought resistant crop varieties
3. New crop/livestock systems resulting in improved precipitation use efficiency
4. Improved irrigation water use efficiency at the field-level increasing farm profitability and sustainability
5. Increased irrigation water use efficiency by urban water users reducing urban water demand
6. An international reputation for excellence in field-level water optimization

C. Undergraduate Curricular Innovations

More fully engaging undergraduate students in the programs the College offers will improve awareness of food systems and the environment. This can be accomplished through the development of new and relevant curricula within the College composed of existing courses clustered into 16-21 credit hours blocks that reflect the proposed strategic initiatives. These new curricula, along with an already existing and robust Agricultural Education program, can attract new students into the College and engage them in timely and relevant programs that address critical issues. The education of our future teachers and agricultural leaders is vital to the success of many of these initiatives and the issues the world population is facing. Through an enhanced distance education program the College can be a leader in the role of educating those who will address food system and environmental issues.

Strategic Initiatives Position Papers

Assuring Food Safety and Quality

Background information

Faculty in Animal Sciences and Food Science and Human Nutrition that conduct food safety and quality research comprise the Center for Meat Safety and Quality (CMSQ). The CMSQ is a primary research contributor to the Food Safety Cluster of the Infectious Diseases Supercluster at CSU. In addition, the CMSQ is listed at CSU as a program for Research and Scholarly Excellence (PRSE) for 2008-2012. Faculty in the CMSQ interact and collaborate with colleagues from several colleges and departments to teach undergraduate and graduate courses as part of the Interdisciplinary Studies Program in Food Science and Safety. Likewise, the CMSQ collaborates across departments, colleges, other universities, and with government entities to address important applied industrial and social issues. The CMSQ is highly visible on a national and international level, and undergraduate and graduate students generated as a product of the program are in high demand and rapidly becoming academic and industry leaders across all sectors of food production, distribution, and retailing.

The applied discipline of “Meat Science” is extremely broad in the sense that it focuses upon the manner in which harvested animals are produced and on the safety and sensory characteristics associated with the marketing of fresh beef, pork and lamb. Specific needs are to assure that US fresh meat is acceptable to both domestic and international markets and performs beyond expectation when consumed. A critical scientific issue involves providing assurances, through research studies, to customers (those who purchase livestock and/or meat products) and consumers (those who eat meat products) that animals, fresh meat and meat products are chemically and biologically safe and of a eating quality level in line with expectations. Much has been done to assist industry with research results intended to help solve problems related to *Escherichia coli* O157:H7 in fresh beef, *Listeria monocytogenes* in processed meat products, and bovine spongiform encephalopathy in beef.

As new food safety issues develop (e.g., the advent of antimicrobial resistance of food-borne pathogens), it will be increasingly important that proactive scientific investigation occurs so that policy-makers have access to the necessary factual information from which sound decisions may be made, and that society as a whole has access to credible information regarding risks. As technology resulting from meat science/food safety research is implemented, effects of adjusted management practices at all sectors of the supply chain must be assessed to ensure that eating quality and desirability have not been compromised. Additionally, new technologies that improve product quality and that are consistent with evolving food safety practices (e.g., instrument assessment of carcasses for purposes of establishing marketing value) must also be developed, researched, and adopted; and outreach must occur to prevent artificial barriers to trade as a consequence of using the new technologies. As new technologies evolve as a consequence of research, the economic merit of installing such technologies in industry must be demonstrated to ensure financially beneficial adoption.

Problems we are addressing

One of the most pertinent industry issues is to assure, through research and outreach efforts, that livestock producers, packers, and processors generate products from animals that were reared in an animal husbandry manner, handled appropriately, and fed to assure generation of desirable, healthful and safe meat products for subsequent sale/distribution in domestic and global markets. Global consumer confidence in the quality, sensory characteristics, wholesomeness and safety of food products is critical to ensuring demand, and thus sustainable economic prosperity for those involved in agricultural production, marketing, processing, distribution, retailing, foodservice, and peripherally-

related businesses. In Colorado, the ramifications of not adequately providing consumer confidence in meat safety were demonstrated when Swift & Co. (subsequently JBS S.A., Inc.) in Greeley, CO was forced to reduce production by a full shift and lay off over 800 employees due to export restrictions imposed as a result of the single case of Bovine Spongiform Encephalopathy detected in the State of Washington. Likewise, use of chemical antimicrobial intervention systems by U.S. processors has led to imposition of trade barriers for the export of U.S. products into Europe and Russia; and outreach efforts to communicate the benefits of using such systems are needed to restore and increase global trade.

With respect to critical human issues, public health continues to improve as exposure to agents that cause food-borne illness is reduced and/or controlled. Secondly, the general public's expression of "outrage" due to a public health threat is directly and historically suppressed as manufacturers take proactive and publicly visible steps to reduce threats to health. When society at large is involved in the risk assessment process, many crises may be avoided. The third critical human issue, as previously described, is to assure through research and outreach endeavors, that stakeholders that are livestock producers have profitable and sustainable operations (farms, ranches and feedlots), that those stakeholders who harvest or process animals and their products remain profitable and competitive, and that customers and consumers, here and internationally, obtain safe, wholesome, and highly-desirable animal-food products.

Scope/Audience

This initiative will impact undergraduate and graduate students, rural, periurban and urban-citizens, and the food and agricultural industries within the state of Colorado, the USA, and the world. A new combined BSc/MSc program will adequately train students to compete for leadership positions in academia, government and industry. An integrated educational program will also enhance the current research activities of the Center for Meat Safety and Quality, and the Food Safety Cluster, by enhancing recruitment of high quality graduate students to these research programs. Consumers will benefit from this initiative through the transference of trained personnel and food safety interventions to the food and agricultural industries, which will lead to the enhanced production of safe food. The faculty within the CMSQ and Food Safety Cluster have developed a long history of transferring food safety solutions to the agricultural community as evidenced by the fact that several interventions to control pathogenic bacteria during meat production, that were developed at CSU by these faculty have been formally recognized and suggested for implementation at meat plants by the USDA FSIS. This initiative will enhance such efforts, further strengthening the competitiveness of food companies and agricultural facilities within the state of Colorado, but also across the USA and the world. Finally, active outreach programs will lead to meaningful connections with Colorado food companies such as Denver based Leprino Foods, that is currently building a new facility in Greeley, and will enhance ongoing relationships with current industrial partners, such as JBS S.A., Inc. Finally, the international reputation of the CAS and University as a whole will be enhanced through strategic approaches allowing food safety Faculty to address emerging food safety concerns that may occur in other parts of the world, and develop solutions to solve such issues before they affect the USA.

The science team

Food safety is a dynamic area, as denoted by faculty involvement in four colleges and seven Departments at CSU, and the Colorado Water Institute. In addition, Faculty collaborate to teach undergraduate and graduate courses that comprise part of the Interdisciplinary Studies Program in Food Science and Safety. The program is a cooperative effort of faculty in seven departments and three colleges within the University who share a common interest in food quality, safety and integrated production and processing. Animal Sciences faculty that conduct food safety research, along with Faculty in the Department of Food Science and Human Nutrition, form the Center for Meat Safety and

Quality (CMSQ). The CMSQ constitutes the Food Safety Cluster of the Infectious Diseases Supercluster at CSU. The effectiveness of the CMSQ to solve food safety related problems is highlighted by the following:

- Since 2003, the CMSQ has attracted more than \$16 million in grants and contracts to conduct food safety and quality research.
- During that same period, CMSQ faculty have published more than 166 peer reviewed publications.
- The CMSQ has been selected as a Colorado State University Program for Research and Scholarly Excellence (PRSE) for the period 2008-2012.

Future research and educational opportunities for CAS food safety Faculty exist through interactions in the Colorado School of Public Health, Master of Public Health Program. However, it is clear that there are several acute needs that must be addressed in order for food safety Faculty within the CAS to remain nationally and globally competitive. Such needs are highlighted below, including:

1. A lack of expertise in muscle/lipid biochemistry and post-mortem metabolism research/instruction and a significant need for benchtop chemistry analytical expertise.
2. A need for faculty with expertise in the areas of food virology and/or toxicology and a need to improve competitiveness for extramural funding and to instruct students in these areas.
3. The CMSQ and Food Safety Cluster program currently lacks specific expertise in food safety and quality economics and business, and such expertise should be considered for inclusion within CMSQ. Such expertise currently exists within CAS (e.g., Dr. Dustin Pendell), but use of such expertise to address CMSQ goals would require either resource reallocation to cover resident instruction obligations in the Agricultural and Resource Economics department or creation of additional support to offset resident instruction needs.
4. Modernization and expansion of laboratory space is needed to improve technical capabilities in food microbiology. Likewise, no modern research laboratory space currently is available for use in the areas of food virology, food toxicology, or muscle/lipid biochemistry. Lastly, no teaching laboratories are available currently for any of the aforementioned disciplines.
5. The addition of two new education programs would serve a currently untapped pool of potential students; those already in the trade and those who wish to earn a technical B.S./M.S. degree in five years or less. Establishment of a strong distance learning program for credit (i.e., using the CSU's MBA program format) in conjunction with a five-year B.S./M.S. degree program in Meat Science/Food Safety would serve these two groups of clientele while potentially generating significant additional revenues for CMSQ, the department, and CAS. A coordinator with diverse expertise in meat safety and quality education is needed to develop and coordinate such programs if they are to become a reality and be implemented.

Proposal

The following objectives in research, education, and outreach are proposed:

Research

1. Development of a research program in muscle/lipid biochemistry and post-mortem metabolism.

The need for a research program in muscle/lipid biochemistry and post-mortem metabolism has been identified as acute, because, via attrition in faculty, expertise in this area no longer exists within CMSQ. Such a handicap affects competitiveness for extramural support and grants, as well as instruction, particularly at the graduate level. A faculty position in this area is also needed (see Resources needed below). The new hire would be required to submit grants and work collaboratively with existing faculty within CMSQ (as well as colleagues outside of CMSQ) to conduct state-of-the-art research addressing a range of topics that include pre-harvest and post-harvest animal welfare and

stress, product eating quality, human nutrition and diet-health, fatty acid composition, muscle contraction, and ramifications to product quality of incorporating antimicrobial treatments into industrial processing systems as a component of food safety management. The research program would lead to the development of an array of benchtop laboratory techniques associated with protein separation and analysis, lipid metabolism and fatty acid composition, muscle and lipid growth and development, and diagnostics. Such a research program would also be particularly positioned to lead to the development of educational programs during which the research topics could be developed into hands-on laboratory classes, offered to graduate students that address fundamentals associated with basic muscle/lipid biochemistry and physiology, which would advance current graduate training significantly and dramatically improve competitiveness of students particularly for academic and R&D positions within industry.

2. Development of a research program in food virology.

A research program in the area of food-borne viruses is an acute need, especially when one considers that food-borne viruses cause almost 70% of all food-borne outbreaks where an etiologic agent is identified. The need for such a program within CAS and the CMSQ and Food Safety Cluster is perhaps best explained by noting that the USDA Agriculture and Food Research Initiative Competitive Grants Program has set aside \$30 million dollars in the 2010 competition specifically directed at food virology research as a special emphasis, and due to the lack of a program in this area, the CMSQ is unable to apply for these research funds. It is expected that a program in food virology research would develop studies to evaluate the occurrence and fate of food-borne viruses in food (produce, seafood, etc) in order to assess their potential risk to food safety and human health from pre-harvest through consumption. The program would include efforts to identify and characterize unknown viral etiological causes of food contamination, and should lead to new detection methods that should detect low levels of food-borne viral contamination and detect infectious viruses. Current food production and processing practices would be evaluated and improved to increase control or facilitate elimination of viruses in foods. Control methods would include the development and implementation of novel and effective food processing technologies and novel post harvest interventions for eliminating or controlling viruses in or on foods, including seafood and fresh produce.

3. Development of a Diagnostic Core Research Facility.

In support of the above research programs, as well as ongoing research within the CMSQ and the Food Safety Cluster, it is proposed that a diagnostic core research facility be developed. Since a major aspect of food safety research at CSU is related to the development of methods to detect the agents of disease, a logical next step in the progression of research capability within the CMSQ, the CAS, and the University as a whole would be the development of a Diagnostic Development Laboratory that would add value to the existing University core facilities, while enhancing the ability of CMSQ faculty to attract extramural research funds, and to develop the next generation of diagnostic assays needed in the global fight against food-borne disease. The Laboratory would house equipment used to develop rapid lab-based and point of care based diagnostics to detect pathogenic microorganisms (parasites, viruses, and bacteria) that are important vehicles of food-borne disease. Major equipment that would be present in the Laboratory (and currently available to faculty in the CMSQ includes: a BioRad BioPlex, bead-based flow cytometer system, a Biotek HT Synergy multilabel plate reader, a Pathatrix automated immunomagnetic separation device, a suite of equipment used for the development and mass production of lateral flow devices and a large -80oC freezer to store reagents and samples for analysis.

Education -- Development and implementation of a five-year B.S./M.S. on-campus program in Meat Science/Food Safety in conjunction with a substantive distance learning degree program.

The CMSQ seeks to develop two new educational curricula tracks intended to produce students with both a B.S. and M.S. in a five-year program. To service an increasing number of personnel already employed in the industry, but whom also wish to further their education and obtain a technical B.S. or M.S. degree while maintaining their employment, this new faculty member would also be charged with developing curricula for credit in a distance learning format, similar to that utilized by the College of Business in the “Executive MBA” program. These curricula programs would build off of foundational courses in Animal Sciences, Agribusiness, Food Science, Human Nutrition, and other disciplines.

Ideally, “B.S./M.S.” students will complete course requirements for the baccalaureate degree in 3.5 years and a subsequent Masters degree in an additional 1.5 years with, at minimum, two summers spent in eventual-employment-arena work study/internship programs plus one summer devoted to conducting field-research study. Specific interdisciplinary curricula would be developed with extensive inputs of potential employers of “B.S./M.S.” graduates in a meat science/food safety education pattern track (e.g., JBS S.A., Inc). This radically innovative new direction in student matriculation would position Colorado State University as being truly responsive to the needs of those most likely to employ graduates of our programs.

In conjunction with a five-year degree program, distance learning has become increasingly popular, particularly for those who are already employed in the workforce. There were an estimated 12.2 million enrollments (or registrations) in college-level credit-granting distance education courses in 2006–07. Of those enrollments, 77% were reported in online courses, 12% were reported in hybrid/blended online courses, and 10% were reported in other types of distance education courses. In 2006–07, there were over 11,000 college-level programs that were designed to be completed totally through distance education (66% were reported as degree programs and 34% were as certificate programs). Existing Faculty in CMSQ receive, on average, 10 to 20 requests each year from high-ranking corporate industry personnel that would like to obtain advanced technical degrees via distance learning, since they cannot afford to pursue such goals otherwise. This specific focus would allow training of individuals in advanced meat science/food safety topics that are unable to attend classes on-campus at CSU. Specifically and in conjunction with the “B.S./M.S.” degree program, we propose to create an online degree program in which an individual could obtain B.S. and/or M.S. degrees in meat science/food safety, most likely in an “executive” format. The demand for this degree would be relatively large as it would be one of the first of its kind in the U.S.

Development of an on-campus and distance learning five-year “B.S./M.S.” program that addresses the scientific, industry and human issues in meat science and meat safety programs will lure more talented out of state and international students to CSU, increasing tuition dollars and extramural funding opportunities. If CMSQ further succeeds in developing and enhancing CSU’s already outstanding national and international reputation in meat, animal, and food safety, it will create even greater demand for our students from academic institutions, governments and industry. The distance learning component of the program would offer significant potential to increase CAS revenue substantially (i.e., as it has in the College of Business).

Outreach and Evaluation of success

The obvious measures of success will be the number of students that enroll in this program. The program will be evaluated on a regular basis with consultation from leaders in the federal (APHIS, FAS, FSIS, etc.), state (CDA, CDPHE, etc.), and local (Larimer County Health Dept., etc.) governments, industry (JBS S.A., Cargill Meat Solutions, etc.), and trade organizations (NCBA, CCA, CLA, ASI, NPB, USMEF, AMI, NMA). A major objective of the Meat Safety and Quality Strategic Initiative will be to provide outreach education to industry, regulatory and public health agencies, and consumers. Educational materials will

be designed by CMSQ faculty to support implementation of training workshops, which will focus on transferring meat safety and quality knowledge to stakeholders within the meat industry. A significant effort will focus on reaching small meat processors who are often overlooked during outreach activities. Upon attending the workshops, participants will be able to use the educational tools and knowledge gained to implement the new meat safety and quality processes within their respective plants. Equipment manufacturers will be able to use the knowledge to optimize their equipment to effect more efficient use of the processing technologies to increase the microbial safety of meat products. Impact evaluations developed from a Logic Model, will lead to an understanding of effective communication strategies that will encourage stakeholders to adopt the new knowledge that will be developed as part of this Initiative. Most importantly, impact evaluations regarding the research and education to be conducted during this initiative will yield results which can be concisely communicated to stakeholders, leading to effective dissemination of knowledge. Once the impact evaluations have been completed, the impacts of the Initiative will be reported using a variety of methods including publication in peer-reviewed journals and other avenues to ensure that the research results and educational tools and programs are more generally available. Presentations will be made at international and national scientific meetings, and will be used to communicate information to academics, government personnel, and other meat industry stakeholders who may be interested in the information but did not attend the workshops.

Resources needed

1. Establish a new Meat Science Coordinator position (with meat science education as an area of expertise). This new position would have an obligation to develop and implement a five-year B.S./M.S. on-campus program in Meat Science/Food Safety in conjunction with a substantive distance learning degree program.
2. Establish a new tenure-track faculty position, in muscle/lipid biochemistry and post-mortem metabolism. This individual will augment current research programs, add a missing basic science component to the program, and contribute training at the graduate level.
3. Hire one additional tenure-track faculty member in Agricultural Economics. This individual will contribute to the Agribusiness and Agricultural Economics program with regards to Resident Instruction. The research will focus on meat science/food safety issues (e.g., consumer demand for food safety attributes, emerging private and public mechanisms from the farm to the retail level to improve safety of domestic and imported food supply, food safety systems in major U.S. food import markets, economics of the U.S. food traceability, labeling, certification and inspection systems, assessing the impact of government food safety regulations, valuing the benefits and costs of greater food safety, etc.) and be added to the CMSQ.
4. Modernization and expansion of laboratory space is needed to improve technical capabilities in food microbiology. Likewise, no modern research laboratory space currently is available for use in the areas of food virology, food toxicology, or muscle/lipid biochemistry. Lastly, no teaching laboratories are available currently for any of the aforementioned disciplines.

Improving Food for Enhanced Human Health (Crops for Health™)

Background information

Biomedical Agriculture. Agriculture has exciting potential to become an increasingly effective instrument of public health worldwide, because food is the primary and most efficient vehicle for the delivery of health promoting chemicals to the human body. Research and education that enables us to understand and take greater advantage of the ways in which food components help prevent chronic and enteric diseases can greatly reduce the physical, psychosocial and economic impacts of such disease worldwide. The research and education required to understand and improve food for health is transdisciplinary, engaging agricultural, biomedical, and social scientists in new programs of discovery, dissemination, and training. In its broadest sense, this transdisciplinary approach and emerging field can be termed Biomedical Agriculture (Thompson & Thompson. 2009. *Advances in Agronomy*. 102: 1-54.).

Crops for Health™. An anchor program at CSU that is a hallmark of this strategic initiative is Crops for Health™ (CFH), a program of plant based research and education centered on health enhancement through a diet based approach. CFH is a branded program within the broader context of Biomedical Agriculture, with the ultimate goal of identifying specific genotypes (e.g. varieties) of food crops which reduce risk for chronic diseases such as cancer, cardiovascular disease, type II diabetes, and obesity as well as the prevalence of enteric diarrheal diseases. Developing new crop cultivars with enhanced disease-preventing qualities can also benefit the producers of major crops (e.g. dry beans, potato, wheat) by adding value to their products in the marketplace.

Problems we are addressing

The primary problem is the impact of chronic diseases on the populations and economies of the world. According to the Centers for Disease Control, seven of every 10 deaths in the US are attributed to chronic diseases, and these diseases are in large part a consequence of diet. Chronic diseases such as obesity, type-2 diabetes, cardiovascular and cerebrovascular diseases, and cancer are among the most prevalent, costly, and preventable of all health problems. Enteric diseases, including the dehydrating and malnourishing diarrheal diseases, globally account for the deaths of more than 6,800 children per day, and are often associated with poverty. What links these two extreme examples is that food-based dietary interventions may reduce the impacts of both chronic and enteric diseases. Enhancing and sustaining human health by improving food quality and availability to prevent disease is a grand global challenge, one for which the benefits of problem solving exceed the scope of the challenge. Maintaining the profitability of crop producers is another problem that will be addressed as progress is made in developing crops for health with added value, that is, new varieties from basic research and targeted plant breeding.

Scope/Audience

The scope, and those to be impacted by the work toward this initiative, are extensive and world-wide. This is especially true because the primary focus will be on staple crops consumed by much of the world's population. The chronic diseases, including obesity and cancer, are increasingly global problems, and enteric diseases impact children in developing countries, so substantive improvement and adoption of staple crop varieties has the potential to positively impact millions of consumers.

The growers of staple crops in Colorado and elsewhere also will benefit through increased demand and value of crops for which improved human health benefits can be proven.

Students seeking career preparation at the interface between agriculture and medicine also comprise an important audience for this strategic initiative, because the proposed activities include near term development of a transdisciplinary graduate program of study in Biomedical Agriculture (BMA), and related opportunities for undergraduate students.

The science team

CFH researchers are active, experienced, enthusiastic, committed, and have the skills needed to: (1) identify and characterize genetic diversity related to health benefits among staple crop species, (2) assess the contributions of metabolites for human and animal chronic and enteric diseases, (3) accumulate health beneficial attributes into staple crop species via plant breeding, and (4) educate the population on the benefits of those traits. Thus, our current faculty have significant expertise to identify and utilize crop genetic diversity for health benefits.

Researchers at CSU have a long history of providing improved crop varieties and management practices to enhance wheat, common bean, and potato production. We are uniquely positioned to combine long-standing excellence in plant breeding and associated programs with contemporary plant biochemistry/metabolomics and human nutrition/disease prevention research capacity. Initial collaboration between biomedical and agricultural scientists at CSU has revealed a wealth of genetic variation for disease prevention in food crops of economic importance to Colorado and globally. Recent work is also exploring whether staple crop products can augment gastrointestinal mucosal immunity, and protect against diarrheal infections.

Crops for Health™ findings are directly relevant to goals of multiple funding agencies including the National Institutes of Health, the National Institute of Food and Agriculture, the Gates Foundation, the Centers for Disease Control, the National Science Foundation, the National Aeronautics and Space Administration and the Department of Defense (NASA and DOD interest is related to crop characteristics likely to help sustain human physical performance under stressful conditions, e.g. military service and manned space flight).

During the Spring semester of 2009, the School of Global Environmental Sustainability (SoGES) sponsored an inaugural series of four research working groups, of which Crops for Health™ was one. Establishment of the CFH working group has highlighted the multidisciplinary span of related interest and assets at CSU. In the 2009 meetings, there were 33 CFH participants, representing 5 colleges, 12 departments, CSU International Programs, the Colorado School of Public Health, NREL, and the community. In a Fall 2010 series of meetings, additional participants included the Poudre Valley Health System Foundation, McKee Medical Center, and the CanDo community outreach program. Into the future, although led by CSU, the success of CFH will rely on integration of different disciplines across the university and local community as well as the national and global agricultural and biomedical research and outreach communities.

Although existing expertise is strong, a number of major gaps exist for the future success of CFH. These include:

- expertise in plant primary and secondary metabolism/biochemistry, i.e., a faculty member who can identify the bioactive metabolites, predict their biosynthetic pathway, and suggest how they might function in conferring health benefits.
- bioinformatics capability to apply findings across crops and to leverage knowledge from crops with relatively simple genomes (e.g. rice and common bean) to more complex genomes such as wheat and potato. Such expertise is required to accelerate the rate and breadth of development of beneficial crop varieties.
- an additional faculty member whose training is grounded in the biomedical sciences and whose primary commitment is to work with agricultural scientists to identify health beneficial crop varieties. This scientist must be extensively trained in the evaluation of high dimensional mammalian datasets resulting from genomic, proteomic, and metabolomic evaluation of human

and animal tissues and have expertise in the metabolic defects characteristic of obesity, type-2 diabetes, and cardiovascular and cerebrovascular diseases.

Also, several faculty who play a prominent role in CFH are approaching retirement. It is critical that their expertise be replaced and complemented via a pattern of faculty hiring that retains CSU's strengths in plant breeding and builds a transdisciplinary faculty committed to both the biomedical and agricultural aspects of CFH.

Proposal

The ultimate goal of the CFH initiative is to understand and thereby improve the human health benefits of food crop varieties, and to provide consumers with those varieties for which we have evidence of enhanced health benefits. The overall strategy is to tap natural genetic diversity within staple crops to improve their value in the diet. This is a markedly distinct approach compared to programs that rely on pharmaceuticals or nutritional supplements. Furthermore, CSU's CFH program is unique because it represents an effort to exploit crop genetic diversity not solely for improving the classically targeted phyto-nutrients, but also for phyto-chemicals, including both primary and secondary metabolites of plants, that have health related benefits and can reduce the prevalence of chronic and enteric diseases. The CFH premise is that staple foods, which are affordable and eaten in large quantities daily by the populations of the world, are the primary vehicle by which health promoting chemicals are delivered to the human body, and that the health promoting nature of the diet can be shaped by identifying food crop traits that agricultural practice can and should improve.

Research

To achieve this goal, a systematic approach is required that investigates staple and specialty crop genotypes for bioactivity that translates into improved disease biomarkers, alterations of which are associated with reduced disease risk. The primary mechanisms targeted for food-mediated disease risk reduction are altered glucose metabolism, chronic inflammation, excessive cellular oxidation, chronic endotoxemia, and improved mucosal immunity. The crop improvement process via BMA is tiered, establishing efficacy for disease prevention in molecular, cellular, and animal investigations of crop genotypes and food combinations before evaluation in cohorts of human participants. Ultimately, specific dietary plans will be tailored for individuals at risk for one or more chronic or enteric diseases. Informatics and omics technologies enable transdisciplinary collaborations, giving the agricultural and biomedical sciences a common research setting that sustains and translates progress into the community.

Specific research projects will aim to:

- Identify plant biosynthetic pathways and bioactive compounds that enhance human and animal health. Associated with this are the needs to develop accurate and high through-put methods for measuring activity of these key pathways and bioactive compounds in crop varieties that allow for assessing germplasm and as selection criteria in plant breeding programs.
- Understand the genetic regulation of biosynthetic pathways associated with health benefits.
- Understand the basis for how plant bioactive compounds enhance health.
- Develop accurate and high through-put methods for measuring activity of these key pathways and bioactive compounds in crop varieties that allow for assessing germplasm and as selection criteria in plant breeding programs.
- Incorporate this knowledge in plant breeding programs to maximize the health promoting qualities of commercial crop varieties.
- Develop frameworks for health-promoting crop production and use by consumers while determining how these improved crops and the foods derived from them can be sustainably delivered to benefit populations around the world.

Teaching

Scientists trained at the transdisciplinary interface that is Biomedical Agriculture are needed to advance our understanding of how human health is/can be promoted by fruit, grain and vegetable crops in the diet. Much more needs to be known about: the mechanisms whereby food crop genotypes can prevent chronic diseases; ways to improve genotypes for maximum health promoting potential; and how to best disseminate this knowledge to the global public health community. The coalescing of scientists from fields of study such as human nutrition, chronic disease prevention, epidemiology, plant genetics and diversity, plant biochemistry, and agricultural crop breeding and production, offers the complementarity and synergy needed for agriculture to realize its promise as an instrument of public health worldwide. Colorado State University can be the world leader in this effort with the creation of the first advanced degree in Biomedical Agriculture.

Specific teaching initiatives will include:

- Formal opportunities for undergraduate student research experiences. Experiential learning will rely on substantive interaction that integrates multiple disciplines. It is expected that students will comprise two broad groups – those interested in agricultural science with a biomedical focus and those interested in biomedical science with an agricultural focus.
- A new graduate degree granting program for the training of students in Biomedical Agriculture in the next two years with growth in student enrollment to 25 after five years. The goal is to have all students fully supported by research assistantships. Graduate training will embrace the concepts of 1) a competency based curriculum; 2) co-mentorship by experts in agricultural and biomedical sciences; and 3) the completion of a project that includes elements of plant and animal research. Training will include plant genetics and breeding, statistical methods for agriculture and biomedical research, experience with ‘omics’ technologies and bioinformatic techniques, and course work that exposes students to concepts spanning plant and biomedical sciences. An initial draft outlining a BMA graduate degree program has been prepared and will be further developed to maximize the involvement of several Colleges at CSU.
- Meeting the demand for undergraduate coursework in Biomedical Agriculture with periodic assessment of the need for and feasibility of establishing an interdisciplinary undergraduate program of study in this topic. This will be done by development of a series of transdisciplinary courses designed to educate the undergraduate population about the global challenges that CSU faculty address including those in Biomedical Agriculture.

Outreach

Successful dissemination of research-based knowledge and materials, including new varieties and diet protocols, will require early collaboration among scientists in agricultural and biomedical sciences, and the involvement of the private sector (industry), education professionals, and the public (the consumers). There is little value in pursuing a crop variety with a health promoting trait if health care professionals do not believe it to be of value. If there is no value placed in the trait, then consumers will not demand the variety and growers will not grow it. We propose to establish an external advisory committee with representatives from commodity groups and community stakeholders, the private sector, and the international community to advise the CFH initiative.

Outreach efforts are expected to involve the:

- Scientific community- hosting national and international conferences on Biomedical Agriculture every other year.

- Public- launching public health interventions that are food-based: first locally, then regionally while building collaborations to allow national and international efforts.
- Private sector - establishing formal agreements for field to table dissemination of staple crops with identified health benefits. Potential corporations with which contacts exist include: ConAgra, Seminis, Kellogg's, Bush Brothers, Archer Daniels Midland, Green Giant and General Mills.

Beyond CSU, collaborations, and/or relationships that will enable active collaboration, required for successful transdisciplinary work, are in place with colleagues at numerous other universities, the Scottish Crop Research Institute, several international crop research centers, health care providers in the area, and the food companies listed above.

Evaluation of success

Success of the Crops for Health™ initiative will be indicated by:

- Identification of bioactive compounds or biosynthetic pathways in important staple crops that enhance health.
- Expedited development of staple crop varieties with improved health-related attributes without compromising traits that make them economically and environmentally viable to grow and distribute in the global market place. Release of at least one “health beneficial cultivar” for wheat, rice, common bean, and potato over the next five years with the goal of having additional releases on a regular basis after the initial 5 year developmental period.
- Established protocols and research methods that can be used in clinical studies to determine health-related attributes of crops and their products in human and animal diets.
- Expanded CFH disease prevention efforts to include obesity, diabetes, and heart disease in addition to cancer and enteric diseases and to enhance human stamina in extreme environments.
- Increased external competitive funding for CFH research at a rate of 15 to 20% per annum over the next 10 years.
- Documented participation of undergraduate students in CFH research.
- Implementation of the Biomedical Agriculture graduate degree program, and its growth to at least 25 enrolled students by 2017.
- Active planning to bring the CFH approach to the entire diet, i.e. expanding Biomedical Agriculture to incorporate the animal and meat sciences.

Resources needed

The most pressing needs are for faculty positions, and the start-up funds to assure their success. It is imperative that current program strength in plant breeding and associated areas be sustained by replacing faculty who are nearing retirement. In addition, at least three new faculty positions are required, as specified above (# 4, Science team), i.e. 1. plant metabolism/biochemistry with focus on metabolomics, 2. genomics/bioinformatics, 3. biomedical agriculture scientist.

Developing Profitable and Environmentally Sound Beef and Dairy Production Systems

Background Information

Colorado's beef and dairy production industries are important cornerstones of the state economy, providing \$4 billion in annual revenues via meat animal and dairy product sales. In 2007, livestock and livestock products accounted for 68% of all agriculture sales in Colorado. The production of meat and milk protein spans a continuum of important environmental, economic, and social issues that affect every region of the state.

Maintaining a profitable beef and dairy sector in the face of increasing environmental concerns may be one of agriculture's greatest challenges, and also one of its greatest opportunities. To remain competitive and sustainable, Colorado producers must increase production efficiency and profitability while improving and capitalizing on environmental stewardship – a demanding request during a period of economic uncertainty, smaller profit margins, and external competition for land and resources.

Problems we are Addressing

Increasing Efficiency. Beef and dairy producers will increasingly need to do more with less. As the global human population increases, demand for beef and dairy products will also increase; however, global resources like land and water will not. Improving production efficiency is a solution to the challenge of remaining economically viable and stretching limited natural resources, and is a win-win for producers and the environment.

Historically, increasing production efficiency (i.e., more product with lower inputs) has benefited both producers and the environment. For example, increased efficiency of milk production over the last 25 years has greatly reduced GHG emissions per quantity of milk produced (FAO, 2010). In the beef industry, improved feed utilization through changes in diet, genetics, and management has led to improved gains while reducing nutrient losses during manure handling (i.e., per pound of beef produced). Improvements in efficiency – along with improvements in demand – are the main sources of improved profitability especially relative to less innovative producers.

Unfortunately, there are large differences in efficiency among operations in Colorado. Thus, a goal of the initiative will be to closely examine inputs and production efficiencies by collecting detailed economic and production data from livestock operations across the state. Analysis of this database will identify where improvements can be made while simultaneously reducing environmental impacts.

Carbon Footprints. Public attention to climate change is increasing, and global trends are moving toward regulating carbon in the agricultural sector. In order to navigate complex policy issues and negotiate solutions to pressing climate change issues, the agricultural industry needs a thorough understanding of the role of beef and dairy production in climate change. A life cycle analysis of cattle production is needed so the carbon footprint of beef and milk protein can be accurately quantified.

Livestock production has been identified by the U.N. and the F.A.O. as a major contributor to GHGs (FAO, 2006). Some claim that livestock are responsible for 50% of global GHGs expressed as CO₂ equivalents (Goodland and Anhang, 2009) and suggest that worldwide meat consumption should be reduced. Further investigation suggests that these claims regarding livestock GHGs emissions may be greatly exaggerated (Pitesky et al., 2009), but there is no question that livestock production is under increasing scrutiny in regard to climate change. Unfortunately, the carbon footprint of beef production (GHGs per quantity of product) has not been adequately quantified. Once all sources and sinks of carbon involved in the complete production cycle are considered (rangelands, grain production, land

application of manure, etc.), the carbon footprint of beef production may be much lower than currently predicted. Colorado State University has some of the interdisciplinary expertise to address this issue for the cattle industry, and this foundation in expertise will lead to the development of management practices for reducing GHG emissions and innovative strategies for engaging in emerging carbon markets.

Changing Regulatory Landscapes. New environmental regulations present a shifting landscape for producers, offering both challenges and opportunities. Producers need information on the true effects of beef and dairy production on the environment in order to respond to, and negotiate, regulatory efforts. In addition, producers need information on how to capitalize on existing and future markets that may emerge from regulations. This might include methods to increase profits through carbon sequestration (stemming from cap and trade regulation) or potential income available by providing habitat for endangered species (e.g., sage grouse). Currently, thousands of acres in agricultural production in Colorado are providing habitat for threatened and endangered species, sensitive species, and watershed health; however, few producers are benefitting financially from these efforts. Furthermore, this information can help the agricultural sector in Colorado better communicate the often un-quantified benefits provided by cattle producers to citizens.

Federal and state environmental regulations for livestock are constantly changing, and complying with these new regulations can affect a producer's bottom line. While it is not CSU's role to dictate policy, it is our responsibility to inform the policy making process. Likewise, research and outreach efforts must consider policy and regulations to remain relevant. Finally, science-based information must be provided to both regulatory agencies and commodity groups so new regulations are fair and equitable. An objective of the initiative would be to integrate policy analysis into all components of the livestock and environment effort.

Scope/Audience

Beef and dairy production relies on a complex interconnected system of agricultural practices that include animal science, range management, soil and crop sciences, and economics. A management change at any point in the system can affect the environmental impact and profitability at other points in the system – either positively or negatively. Thus, for any issue, it is crucial that the production system be evaluated as a whole; otherwise changes in management may have unintended effects. Therefore, this Strategic Initiative will include a new research thrust on systems analysis that will integrate across disciplines. A research, education, and outreach framework will be developed so the net effect of management practices can be studied, implemented, and evaluated system-wide while incorporating concepts of efficiency, carbon footprints, ecosystem services, and responses to environmental regulations.

Beef and dairy producers need the latest information on the true environmental effect of their industry, albeit positive or negative, so they can respond to emerging concerns from the public and regulatory agencies. For example, the role of livestock production on greenhouse gases (GHGs) and potential climate change must be addressed in a proactive manner – the agricultural sector needs to understand their contribution to this issue and also how they can be part of the solution to this global concern. In keeping with CSU's Land Grant mission, the College of Agricultural Sciences should be the leader in providing science-based information, analysis, and innovations that Colorado beef and dairy industries need to address these challenges and to capitalize on emerging opportunities.

Science team

The programs outlined in this proposal will be initiated and led by a number of existing and new CSU faculty members in the College of Agricultural Sciences with research, teaching, and outreach appointments. In some cases, these faculty members are affiliated with one or more teams, with a program- or discipline-based focus:

CSU Beef Team: This integrated group consists of approximately 50 on- and off-campus faculty members from several colleges, disciplines, and geographic areas. They support Colorado's beef and dairy industries through events (e.g. field days), media (e.g. websites), and interaction with producers, agencies, and producer groups.

Integrated Resource Management (IRM): This established graduate program and curriculum has an administrative structure with support staff in place, as well as a dedicated classroom for teaching courses and a history of producing holistically trained graduate students.

Institute for Livestock and the Environment (ILE): Faculty members from across the University are conducting interdisciplinary research in topic-areas of key importance including: ecosystems, water quality, air quality, pharmaceuticals, energy, invasive species, and pathogens. Faculty work closely with producers, regulators, and other stakeholders to identify emerging issues, set research direction, and communicate results in a science-based format. This includes the development of Best Management Practices (BMPs) that are technically and environmentally sound, practical and feasible, and result in more profitable and sustainable production through adoption of new practices or technology or risk avoidance.

Livestock Facilities: Unlike most universities, CSU has significant seedstock, cow/calf, and feedyard facilities available for research, teaching, and outreach activities:

- *CSU Agricultural Research, Development, and Education Center* (Fort Collins, CO) – 150 head seedstock cowherd, 200 head Feed Intake Unit with effluent collection capability, 800-head feedyard, metabolism stalls, and support laboratories on 1,000 acres.
- *CSU Eastern Colorado Research Center* (Akron, CO) – 400 commercial cows on a 3,000 acre diversified farming and grazing operation with an 800 head feedyard.
- *CSU Beef Improvement Center* (Saratoga, WY) – 400 Angus seedstock cows at high elevation on 7,500 acres with irrigated meadows, crested wheat grass pasture, and native sagebrush rangeland.
- *CSU Maxwell Ranch* (Livermore, CO) – 350 commercial cows on 11,600 acres of native range.
- *CSU and University of Wyoming Y Cross Ranch* (Cheyenne, WY) – 600 commercial cows on 56,000 acres of native range grazing lands at higher elevation.
- *CSU Southeast Colorado Research Center* (Lamar, CO) – 168 nine or ten head pens in a research feedyard adjacent to the Fiver Rivers Colorado Beef feedyard.

Proposal

Research

Activities will primarily focus on a holistic and life-cycle view of beef and dairy production systems through an interdisciplinary research program. The ultimate goal will be to improve the efficiency of feed utilization relative to outputs (i.e., meat, milk) in order to more efficiently use available grazing and

feed resources. This will need to be accomplished while also reducing the carbon footprint of cattle production and adapting to changing regulatory landscapes. Some key areas of research will include:

Systems Approach to Evaluate Practices: Since the disciplines of animal physiology, forage resources, economic performance, and overall efficiency are tightly linked, producers changing any one aspect of a production system will need to consider impacts on overall system efficiency the environmental.

Producer Practices, Management, and Performance: An automated database of Colorado beef and dairy producer business information will be developed with assistance from the CSU Beef Team. As a result, beef and dairy business budgets and performance goals will be constructed, and through data analysis top and substandard business performance measures will be identified. To encourage participation, these data will provide objective information to producers that will promote innovation, improved efficiency, and improved profitability.

Feed Intake: The variation in feed intake and efficiency among grazing cattle will be evaluated, including factors that influence it. A genetic prediction (as an Expected Progeny Difference, or EPD) will be developed for feed intake/efficiency in cattle, as well as its incorporation into a multiple-trait selection index and/or decision support system. Ultimately, factors that influence the variation in energy required among grazing cattle will be determined.

Grazing: The use of “Managed Grazing”-type practices on cow/calf, stocker, and dairy operations to improve profitability and efficiency of feed utilization will be assessed, including some use of Management-intensive Grazing (MiG) principles. Real and perceived obstacles to adoption of sustainable grazing principles by operations will be identified, as well as an economic evaluation of the application of these concepts. This area of research will be particularly important in the dewatered lands of Colorado, and will integrate with other efforts (e.g., “Innovative Approaches to Limited Water Resources” Strategic Initiative).

Efficiency: The common producer hypothesis that increasing efficiency will reduce environmental impact will be evaluated, including the impact of practices on the efficiency of C, N, and P utilization and the environment. In particular, antibiotics and steroid hormones play a role in increasing efficiencies, but also bring with them additional environmental risks. These tradeoffs among environmental issues must be evaluated, as well.

Carbon Footprints: Biochemical, microbiological, nutritional, and genetic approaches to reduce feed intake, greenhouse gas emissions, and manure production will be evaluated. This will include the identification of substances that inhibit methanogenesis, methods to re-direct fermentation and improve H₂ utilization, and feeds that can influence volatile fatty acid production ratios.

Regulatory Costs and Opportunities: Businesses frequently observe regulation as increased costs, but the public and policy makers often view regulation as internalizing existing costs on the creators of those costs – which is a tension that will not decrease in the future. Internalization of costs within today’s beef and dairy systems is an area where producers have the ability to innovate and improve efficiency. However, little is known about the extent of these costs, and opportunities for new income – specifically with respect to ecosystem services – are uncharted economic and policy territory.

Teaching

The industry has an increasing need for CSU graduates that understand the complexities and management of sustainable and profitable beef and dairy production systems, including societal and economic impacts of management decisions. Profitability has long been a goal of all production systems, but the impact of environmental concerns/legislation is relatively new to production agriculture. The College of Agricultural Sciences at CSU is uniquely positioned to enhance student training through curricular and extra-curricular exposure to the interactions between the environment and cattle production systems, including efforts to:

Develop Interdisciplinary Students: We will develop an international reputation for producing graduates who are able to manage the complexities of a variety of issues surrounding beef and dairy production. The cornerstone of this will be to create an Interdisciplinary Program within the college of Agricultural Sciences for training graduate students. Currently, there are faculty members that have the ability, but not the time to devote to this effort.

Create Environmental Issues Curriculum: A unique graduate curriculum that trains students to deal with environmental issues surrounding beef and dairy production will be created. The curriculum will be centered around profitability, but will address the environmental constraints, challenges, and opportunities as well as the interactions that exist. The curriculum will cross departmental boundaries to provide the best training possible. This curriculum could be administered as significant components of other existing programs (e.g. IRM).

Utilize Relationships: Relationships with other organizations (including governmental agencies) will be fostered so that students will get on-the-ground training and links to potential future employment. Collaboration with the Office of International Studies will be explored to offer study abroad opportunities at institutions with environmental systems expertise. Currently, there are operations that are profitable and environmentally sound that could provide excellent training for our students.

Improve Recruitment: Top tier graduate students will be recruited for participation in these programs and activities. Students will not be selected solely based on academic achievement, but must show an ability to integrate and think holistically. Graduates from this program have the potential to become innovative leaders as this initiative area grows.

Outreach

Our research and education efforts will be fully integrated with our outreach efforts. Existing strong relationships with outreach providers will be leveraged in order to most efficiently interact with the producer base. Planned outreach activities include:

Leverage Existing Infrastructure: Outreach efforts will be coordinated with existing infrastructure, including the CSU Extension Beef Team (through websites and field days), CSU ILE (via website, newsletter, and blog), and several eXtension Communities of Practice including Animal Manure Management, Beef Cattle, and Dairy (including websites, Frequently Asked Questions, and webinars).

Demonstrations: Large-scale, on-farm demonstrations of Best Management Practices (BMP) will be utilized to facilitate dissemination of research results and encourage BMP adoption among beef and dairy producers. These will be coordinated with research efforts to verify the beneficial impacts of new practices while scaling-up.

Webinars: We will host webinars through eXtension to facilitate broader dissemination of CSU-generated information to the Great Plains region and the nation.

Evaluation of success

Ultimately, once this strategic initiative is implemented, the investments in faculty, support, and facilities will result in several measurable results. These include expected increases in: 1) extramural grant funding via the leveraging of infrastructure (faculty, facilities, and support staff), 2) the output of outreach and extension products, 3) scientific publications, 4) recognition and acknowledgement by industry stakeholders, and 5) adoption of CSU-generated management practices and approaches by feedlot, dairy, and ranch managers.

Resources needed

Faculty To be successful in developing the proposed research, teaching, and outreach programs outlined above, significant investment into new faculty positions will be needed. Faculty positions that are needed in order to provide vital leadership and direction to these programs include hiring experts in each of these areas:

- Grazing management and forage utilization
- Life cycle (whole systems) analysis
- Carbon footprint determination
- Maintaining beef and dairy profitability within natural resources and policy constraints

Director This initiative requires a champion to coordinate and provide a face across the state and nation to promote and direct the efforts of this initiative.

Graduate Student and Staff Support Support for faculty members to execute the proposed programs is a major need. In particular, graduate students are the primary need among faculty members within most departments in the college, in addition to operating funds necessary to support research in these areas. Departments that will participate in this program will need to compete with other top universities with agricultural sciences colleges. To do this, the initiative programs must: increase stipends offered, offer summer funding, and offer support for longer time periods. Other universities are doing this, and CSU must change to compete.

Facilities Colorado State University is unique in having ownership and control over several large-scale cow/calf enterprises and feedyards, which can readily provide resources for active research, teaching, and outreach activities. However, activities directly related to the programs highlighted in this paper are currently limited. This is due in part to inadequate support staff (graduate students and technicians) and faculty expertise, and the lack of environmental research-oriented facilities. In particular, there is a strong need for state-of-the-art facilities to address: 1) greenhouse gas emissions research, and 2) replicated grazing research.

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Developing Land Use Strategies for Sustainable Agricultural and Urban Environments

Background information

Although it may be easy to identify urban and rural environments visually, land use boundaries in fact do not fall neatly into these two categories, nor do the benefits that accrue to either category come exclusively from separate, self-contained activities within each area. Rather, intensity of land use and the associated benefits vary along a continuum across these two ends of a spectrum, and the amount of land that falls in the intermediate categories is increasing as the world's population and incomes grow. Urban environments are characterized by large population sizes, high human population densities, and extensive infrastructure, such as roads, commercial and industrial buildings, schools, hospitals, and banks, along with the services and opportunities they provide. Conversely, rural communities have small population sizes and low densities, and, while there is less physical and human capital present in the aggregate (but not necessarily per capita), natural capital such as land, water, minerals, plants, and animals that is scarce in urban environments is found in relative abundance. As urban centers grow, the transition zones from urban to rural environments expand, and the tensions between the needs of contrasting populations become concentrated in these *periurban* areas¹. One assessment estimated that nearly a quarter of prime agricultural land has been lost to urbanization in the US. To make the ideas involved more concrete, consider the following interactions, which will become more commonplace in Colorado over the next decades

- Interactions between wildlife and livestock (Sage grouse and cattle) and humans and wildlife (increasing prevalence of bears, foxes and raccoons in residential areas) will grow as human populations expand; also, fragmentation of habitats for native plants and animals can originate in periurban areas but extend to rural lands, leading to a loss of biodiversity; roadways and other human disturbances provide corridors for the movement of harmful plants and animals.
- As smallholder “ranchettes” grow, former suburbanites must learn how to manage pests and noxious weeds adequately so that agriculture can remain economically viable; both periurban residents and producers will need to learn to coexist; yet, those living in periurban areas may enjoy a lower cost of living and some greater amenities, while benefiting from employment opportunities in nearby population centers, so this growth will likely continue. Agricultural producers can, with adequate technologies, products and management, take advantage of the rising interface with urban land uses to gain markets, increase access to inputs (including labor) and consumers interested in local foods, and find off farm employment opportunities;
- Both agricultural interests and urban dwellers will have to understand the costs that they create for each other: demand for land by urban dwellers will constrain agriculture, raise costs and perhaps condemn rural communities; conversely, agricultural producers may excessively demand infrastructure dollars to support production and distribution networks and utilize production techniques that are at odds with residential requirements.

¹Periurban can be defined as “any expanse of land or region located on the outskirts of a city or town”, and this term is used throughout. However, there are exurban, post-agricultural land and agourbia terms often seen, which suggest various dimensions of the topics considered here. Also, useful perspectives can be seen at <http://web.mit.edu/urbanupgrading/urbanenvironment/issues/rural-urban-linkages.html> and <http://www.thetsrgroup.com/>.

Problems we are addressing

Land use tradeoffs will greatly impact the ability of agriculture to address global challenges such as hunger, alternative energy development, climate change, and environmental and economic sustainability in the 21st century. Some observers suggest that the relative amount of arable land has declined by 50% since the 1960s, from about one acre per person worldwide to just half an acre. Simultaneously, the demand for land services has risen. Key factors include rising urban populations, expanding interest in varied recreational options, intensifying threats to rare and endangered species, increasing pressure to shift agricultural production from food to biomass for alternative energy uses, and diminishing capacity to provide vital ecosystem services such as clean water and air. The need to continually increase agricultural productivity is paramount to meet the demands of a growing worldwide human population.

These global trends are also apparent in Colorado, where the human population has increased by over 1 million between 1970 and 2000, with the urban population growing by nearly 110% while the rural population added nearly 40% during this period. Managing the rural-urban interface in periurban areas and capturing benefits while reducing costs is a central challenge for land use policymakers and stakeholders in Colorado. Colorado has of course seen this interaction expand, with amenity-led growth being prevalent throughout the State and a geography that creates close linkages between the urban, suburban, and agricultural areas in the Front Range, as well as in other parts of the state.

To address these problems, clear understandings needed to be developed with regard to several key areas: (1) the ecological costs and benefits of growth in rural and urban areas; (2) the agricultural challenges as the interface with suburban dwellers grows; (3) the opportunities that can be found or growth, resource conservation, (4) and assessment of externalities in agricultural production and residential growth as they affect resource use, ecological and environmental conditions. There are additionally exogenous factors such as climate change, or changes in international comparative advantages, that will create pressures leading to varying outcomes. With these relations and dynamics understood, the design of alternatives that maximize benefits and reduce costs needed to be put together. To implement improved designs, most importantly, policies must be examined and modeled to find those that minimize costs, are effective, and account for the unintended consequences on ecosystem services and other metrics of benefits. Equally important, a dialogue must be initiated with relevant stakeholders and policy makers for any policy and other recommendations to be utilized.

Scope/Audience

Clearly a large portion of Colorado residents and stakeholders are affected by the tensions and opportunities arising in periurban lands. We plan to address our traditional stakeholders – agricultural interests, rural and urban inhabitants and policy groups -- in new ways, by highlighting the benefits and costs that spill across the spectrum of land activities on the rural urban interface. While we address significant issues of interest to agricultural and other stakeholders, and will help mitigate tensions and address opportunities, we will be simultaneously engaged in outreach and teaching that make insights from Colorado valid in broader contexts than just within the periurban area and the State.

The science team

The many disciplines necessary to study land use and management are distributed across the CSU campus and the broader scientific community here in Colorado. For example, it is clear that rapid environmental change in Colorado will influence the ability of natural, agricultural and urban areas to function effectively and to provide essential services to their populations. Policy makers and planners need timely and relevant scientific information, along with knowledge to explore plausible future

scenarios and make informed decisions. Developing scenarios in the face of irreducible uncertainties is critical to identify opportunities, assess potential impacts, and devise a range of strategies that can inform land use planning and decision making. While, for example, uncertainty in climate change might be inevitable, strategies can be implemented to increase the resilience of human and natural systems to changes in climate conditions and reduce the risks for human health and well being, and much of the physical and social science expertise required exists here at CSU.

Colorado State University and CAS offer many advantages in this area, including 1), a large (>100) cadre of scientists conducting a broad array of empirical agricultural/ecosystem/climate change research with regard to western ecosystems and economies; 2) scientists with over 30 years experience in ecosystem model development, testing, application, and analysis, including economic and agricultural dimensions, and 3) expertise in global change research focused on Human-ecosystem interactions. Moreover, given CAS knowledge of outreach via long experience with Extension, an equally important objective will be to be engaged with policy and issues dialogues among external stakeholders. Finally, over forty classes are taught in various areas of land use. The proposal includes strengthening of the science team with faculty positions in *land use policy and economics* and another at the intersection of *agricultural production and urban ecology*, which together should enhance our ability to undertake research and outreach more effectively on periurban dimensions of land use in Colorado.

Proposal

We will develop the capacity at CSU to investigate, in collaboration with stakeholders, specific types of land use on the rural-urban interface, understand how they compete and interact with each other, and assist in the dialogue about how land resources can be directed to the highest uses. Several main objectives are to ensure sustainable production to support a safe and reliable food supply while, at the same time, maintain long-term protection of land quality and environmental conditions. Moreover, we will enhance understanding of the perceived value, in the broadest sense, of alternative uses of land, ranging from protected lands and open space to high density urban environments. The core activities, both from research and outreach vantage points, are to develop logical and consistent policies to put land to the best uses, especially across the periurban landscapes in Colorado, and to analyze effects of alternative uses on critical factors such as carbon balance, ecosystem services, biodiversity and prosperity.

The proposal includes strengthening the science team with faculty positions in *land use policy and economics* and in *agricultural production and urban ecology*, which together should enhance our ability to undertake research and outreach in regard to the periurban dimensions of land use in Colorado. Equally important, we believe that the coordination of the research, teaching and outreach functions can best be done with an Center for Land Use Analysis (CLUA), which would be similar to the Institute for Livestock and the Environment (ILE) or aspects of the School for Global Environmental Sustainability (SoGES), but with a broader mission than ILE and a greater focus on Colorado agriculture, regional economics and policy than SoGES. The ways in which we expect these efforts to be parts of the CAS mission of teaching, research and outreach include:

Research

Our research work in this strategic initiative will build on the large capacity existing at CSU, but would develop a focus on the interactions between rural and urban areas. In general, we hope to use selected new resources and the CLUA to develop multidisciplinary links to evaluate land use alternatives. A principle role of the Center then would be to pull together skills in these areas at CSU in a coordinated fashion to address issues in a coordinated and synergistic manner as they arise. Selected examples of multidisciplinary work follow:

- Design policies that recognize the loss of *prime* agricultural land and rationalize development to direct growth to complementary areas but that still permit adequate land for housing and commercial enterprises. Research should investigate emerging issues of social equity and poverty as populations grow and put pressure on periurban areas;
- Provide research on benefits to both urban and rural inhabitants from increased recognition of interactions across land uses. Urban areas serve as markets for food, fuel, and fiber produced in periurban areas, and those living in periurban areas may enjoy a lower cost of living and greater amenities, while benefiting from employment opportunities in nearby population centers;
- Review the above options with regard to fragmentation of habitats for native plants and animals and costs (and benefits!) of increasing interactions among humans, their domestic animals, and wildlife in periurban areas;
- Find unique solutions to take advantage of rural and urban resources to address challenges faced specifically by urban-rural interface agriculturists and residents (e.g., biologically based pest management, soil fertility/compost management, companion cropping, water conservation practices, crop and variety trials, agritourism, urban agriculture, economic impacts and efficiencies, regional food systems, post-production handling, and social implications/impact).

Much of the research will be applied in nature and directly applicable to our Colorado urban-rural land uses. Nonetheless, our leadership team believes it will have great opportunity for funding and impact.

Outreach

We expect to expand stakeholder interactions substantially to be fully representative of the periurban land and economy within the state. Most relevant stakeholders are known and CAS interacts with them. However, the engagement will be improved to make sure that entities take into account rural-urban linkages and consequences. Our focus will be on the natural resource, agricultural, environmental and economics portions of this interaction. Utilizing new faculty resources and the enhanced coordination of outreach activities from the CLUA, CAS and CSU can strategically extend existing diverse outreach activities to enable innovative outreach to optimize land use in agricultural and urban environments. Some of the activities related to outreach would be:

- Work with Colorado Extension to develop a more deliberate focus on periurban issues and provide applied research that can improve the outreach capacity in this area;
- Host issues workshops and short courses that bring together diverse stakeholders to examine issues in rural and urban land use;
- Provide policy briefs for various policymakers on the full range of subjects in the area of land use in periurban areas;
- Provide outreach and experiential learning experiences for students.

Teaching

Abundant faculty expertise exists in ecology, economics, range science, public lands management, agricultural production and resource evaluation, landscape design and management, conservation, and invasive species, as evidenced by the 30-40 classes related to land use given at CSU. Our teaching program is strong in many areas of land use associated with less intensive management of land, such as protected areas, and rangeland and farmland. We are not as deep in areas related to the interface between urban and rural land, outside of horticulture and landscape architecture, and less teaching attention is paid to specific Colorado issues. SoGES, established in 2009, will train undergraduate and graduate students to consider social, economic, and environmental aspects of the issues we face, and

collaborate with those trained in entirely different disciplines to address these challenges on trans-disciplinary teams. Our general approach in teaching will be to develop programs in the same spirit as SoGES, but to be more oriented to Colorado, agricultural and economics issues. Our additions on the teaching side will be several fold:

- Strengthen teaching in the areas of most need with periurban emphases;
- Provide interdisciplinary certificates and selected revision to majors as demand warrants;
- Use the CLUA, through its central effort on coordination
- Use regional settings, such the National Ecological Observatory Network (NEON), which has installed observatory platforms to address crucial ecological issues to provide unique educational opportunities for students.

Evaluation of success

Clear measures of success will be found in the performance of the CLUA, where demand for its services by clients around the state, students, and professors, should lead to the following outcomes:

- The number of inquiries regarding issues should rise steadily over the next three years;
- The value of contacts associated with the CLUA should rise to significant levels in three years;
- The professors who utilize the Center should grow;
- Fact sheets should be provided and other links of Colorado Extension should be significant;
- Student interest in new classes and certificates should be firmly established within three years.

Resources needed

Our strategic initiative leadership team believes that enhanced coordination of the diverse activities related to land use in Colorado would bring greater multidisciplinary achievements and would pay large dividends from greater CSU visibility in land management within Colorado. Indeed, we anticipate that this investment would create a multidisciplinary focus that could rival CSU's contributions and reputation in water resources management. We believe that the best way to achieve this greater coordination will be to create an Center for Land Use Analysis (CLUA), which can be similar to the Institute for Livestock and the Environment (ILE) or aspects of the School for Global Environmental Sustainability (SoGES), but with a broader mission than ILE and a greater focus on Colorado agriculture, regional economics and policy than SoGES. We envision that the CLUA will have the ability to assess land use alternatives from economic, carbon foot print, habitat fragmentation, and water and energy use perspectives, among others. A principle role of CLUA would be to pull together the skills in these areas at CSU in a coordinated fashion to address issues as they arise, and to develop initiatives to target areas of need.

Our preferred management approach, and thus resources needed for the CLUA, led by a director-researcher, would be to have a stakeholder Advisory Committee (AC) and selected research and outreach resources provided so that the CLUA will be truly functional from an early stage. The dual role of the Director will be possible because a Center Manager (at a Research Associate level position) would be hired to handle the day to day operations of the Center. An Advisory Committee and dedicated Director will insure responsiveness to the needs of Center staff and current and prospective program participants. Additionally, one other research associate beyond the Center Manager would be required to fully staff the CLUA. We expect that the research associates would be half time and could bring in extra funding by partnering with associated faculty.

Additionally, the gaps identified in our earlier review suggest two main areas where added faculty resources could expand the role and visibility of CSU in land management within Colorado. The

ideal areas for expansion of faculty would be for one faculty member to be in *land use policy and economics* and another should be at the intersection of *agricultural production and ecology*. One of these will serve as *director of the proposed CLUA*, and he/she would then have a dual role as both an administrative leader and active science participant. Thus, we are looking for two new faculty lines.

References

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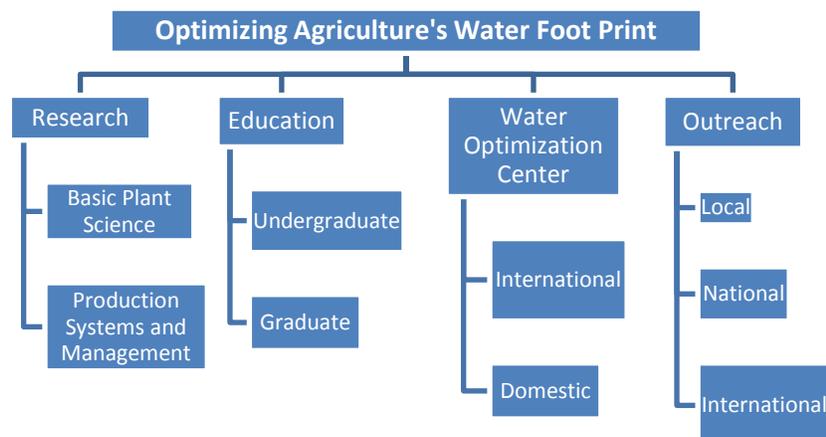
Optimizing Agriculture's Water Foot Print

Background information

Water is an essential ingredient for meeting global food and fiber needs, and communities have grown successfully when harnessing water for agricultural systems. This is particularly true in the Great Plains and the West where precipitation is erratic and agroecosystems evolved to flourish in an uncertain environment. Investments in agriculture and efficient water use create a foundation upon which communities are able to diversify and grow.

But the relationship between water and agriculture systems is dynamic, particularly because burgeoning populations increase the need for food at the same time that they compete for water resources. Moreover, climate change will alter the timing, distribution and demands of water resources globally. Emphasis on bioenergy increases demands for water use in agriculture. Adapting irrigated and non-irrigated agricultural systems to make the most of available water resources is of paramount importance. Worldwide, more than one billion people—nearly a sixth of the world's population—suffer from chronic hunger. Much of the earth's hungry and malnourished population resides in geographic regions prone to drought. These areas now face global climate changes that make their plight even more uncertain. Thus ensuring global food security will only become more challenging in the future as projected demand for food increases by 50 percent over the next 20 years. Considering the recent global decline in the growth of agricultural productivity, mega-challenges are presented by threats from the more erratic precipitation brought on by climate change, the existing scarce fresh water supplies, and the competition for energy resources from industry and urbanization.

Colorado State University and its College of Agriculture Sciences are well positioned to meet these challenges because of its historical successes in meeting the needs of stakeholders with dedicated effort in basic and applied research, undergraduate and graduate education and collaborative outreach. Successfully completing tomorrow's mission requires a reallocation and investment of new resources that enhances the resident instruction, research and outreach missions of the College. The initiative, "Optimizing Agriculture's Water Foot Print", is a plan for meeting the future challenges of water scarcity in Colorado, the region, and the world. The following diagram summarizes the comprehensive and interdisciplinary thrust of the initiative ranging from basic research in plant genomics and management systems to disseminating timely knowledge to the next generation of practitioners and scientists. The subsequent sections of this plan describe the research, education, professional training, and outreach thrusts of the initiative.



Problems we are addressing

Agriculture – in its broadest form – is the greatest consumptive user of water resources in the United States and around the world. Throughout history, leading agricultural enterprises have dealt with changes in climate through changes in management decisions. Over the next two decades, the grand challenge facing agricultural producers will be adapting water management strategies that can adjust to an increasingly variable climate, while at the same time increase production of food, fiber, and energy with less and more uncertain water supplies. The need for increased productivity per unit of water consumed, looms as a huge research challenge to future agricultural production. Adapting agriculture systems to increasing water scarcity demands a unified effort of basic and applied sciences working toward common goals and outcomes. This initiative seeks to build on and add to the strength of CSU's agricultural water research efforts.

While agriculturalists have long been acquainted with managing and conserving natural resources, increasing human populations and climate change will heighten need for water savvy specialists in agricultural water resource management, but it will also require that all undergraduate students have an increased awareness of the agricultural water footprint and the means for making the most of scarce water resources.

Professionals and scientists in the developing world, and in our own nation, are in need of short term training to be updated on new developments and technology in agriculture. There is a large potential market for training and updating national and international professionals. Employees of public agencies, such as USDA-NRCS and USFS, and private consultants have a need for continuing education credits, especially in the soil and water management area. Currently these needs are being met on an ad hoc basis.

Over the past 50-year period, dryland farmers and ranchers in Colorado and surrounding states have specialized in either crops or animals, resulting in wide swings in economic stability. There is mounting evidence that integrated crop/livestock systems are more profitable, more economically stable, more energy efficient, and more environmentally sustainable across the Great Plains region, due in large part to improved precipitation use efficiency. These mixed systems, thus, have significant potential for adapting to water limitations imposed by drought, climate change and other factors such as competition with municipal and industrial demands. Increased research and engagement by CSU could expand the adoption of improved mixed systems optimizing agriculture's water footprint and, thus, mitigating the impact of increasing water scarcity on agriculture systems.

Mixed production systems hold promise not only regionally, but also for many of the world's chronically hungry people living in geographic regions prone to drought. These areas now face global climate changes that make their plight even more uncertain. Integrated crop/livestock dryland production systems will have an important role in ensuring global food security as we are challenged to meet a projected 50% increase in demand for food over the next 20 years. Global agricultural productivity faces similar challenges to those being confronted in the Great Plains and the West: more erratic precipitation brought on by climate change, scarce fresh water supplies, and the competition for water and energy resources from industry and urbanization.

Proposal

We propose to pursue the following objectives in research, education, professional training, and outreach:

Research

The overarching research goal is to improve water productivity in crop, livestock, and energy production systems for water limited agroecosystems. Specific research areas will include:

1. Fundamental research in plant drought stress physiology using model plant and crop species: a) Plant adaptations to water limited conditions; b) Changes in physiological processes due to climate change; c) Genomic studies of basis for plant adaptations to drought.
2. Plant breeding and genetics of drought tolerance and water productivity for model plant and crop species: a) Exploration of available plant genetic resources for water productivity; b) Marker assisted selection approaches; and c) Development, testing, and evaluation of transgenic drought tolerance.
3. Applied production systems management for improved water productivity: a) Dryland cropping systems (interactions of cropping intensity and climate change adaptation; water capture, storage, and use efficiency; pest dynamics and management); Limited irrigation crop production systems (water management approaches to optimize plant performance under water deficit; nutrient management; pest management dynamics; b) optimizing the water footprint of bioenergy systems; and c) Livestock production systems (forage and grazing systems; feedlot systems)

To meet these objectives we propose that CSU establish a dedicated drought evaluation field site to allow careful control of irrigation and monitoring of soil moisture. The drought evaluation field site would need permanent infrastructure i.e. all the associated hardware necessary for precise moisture control and the latest technology for evaluating plant moisture stress, including staff to provide proper management and expertise. In addition, additional faculty expertise in plant breeding for drought tolerance combined with knowledge of “omics” technologies will be key to expanding our capabilities. The drought evaluation field site would allow a “systems” oriented focus on limited irrigation and precision water application.

Undergraduate and Graduate Education

The overall goal of the undergraduate and graduate proposal is to make CSU an international leader in agricultural water resources education. The following steps will leverage the CAS strengths and allow us to achieve that goal.

1. Develop an international reputation for training undergraduate students in agriculture water systems management by: a) Creating an agricultural water resources track within the existing Water Resources Interdisciplinary Studies Program; b) Facilitating the infusion of water resources curriculum within the existing principles courses of the CAS five departments and in selected capstone courses; c) Expanding the agriculture-water systems curriculum to include training in agricultural water quality; d) Reviewing the former agriculture engineering major curriculum and prioritize classes that might be added to CAS; e) Funding an online, undergraduate certification program in agriculture water systems management using a USDA-CSREES Higher Education Challenge Grant; and f) Creating an honors class in agriculture water systems.
2. Foster extracurricular undergraduate experiences in agriculture water systems by: a) Collaborating with the International Studies to offer study abroad opportunities at institutions

with agriculture water systems expertise (In particular, existing arrangements with Lincoln University in New Zealand and with Western Australia;); b) Organizing an interdisciplinary travel class for undergraduate students in agriculture water systems; c) Promoting undergraduate research opportunities with faculty on agriculture water systems projects; d) Developing internship opportunities for undergraduate students in agriculture water systems.

3. Recruit outstanding students for agriculture water systems management by: a) Promoting the agriculture water systems curriculum in key introductory classes; b) Using the FFA CDE contests to promote agriculture water systems curriculum to potential students; c) Working with the Development Office to endow agriculture water systems scholarships; and d) Developing a standardized agriculture major check sheet for students seeking an agriculture water systems track in the water resources ISP.

Professional Training

We propose that CSU establish a “Water Optimization Center” (WOC) that provides instruction on precipitation management in dryland and on management of limited water irrigation systems, using the unifying concept of an optimized water footprint for agriculture. A likely “field lab” site for the WOC is the newly formed Regional Extension Center in Sterling Colorado. The primary goal of the WOC would be to provide a “systems” oriented focus on efficient precipitation and limited irrigation water use. A unique emphasis of the Center would be on mixed crop-livestock systems, which are prevalent in dryland farming areas around the world. We could provide world class experiences in both the formal classroom and in field laboratory settings. There is an excellent opportunity for CSU to work cooperatively with the surrounding states (WY, NE, and KS) that have scientists with national reputations in limited water management systems, which would allow us to provide the breadth of training necessary to be considered world class. Existing research sites at Iliff, Sterling, and Akron, CO and at Sidney, NE and at Lingle, WY would provide field laboratories where trainees would get hands on experience.

Specifically, we would teach students to solve water management problems in a systems context with the ultimate purpose of addressing the closely linked challenges of hunger, health, and climate change. Since most drought prone areas of the world also depend heavily on mixed animal/cropping systems, we would place special emphasis on mixed systems. Research conducted throughout the world shows that establishing profitable, integrated crop/livestock systems is one of the best ways to attack drought. To the best of our knowledge no other university is currently addressing water management at this level.

The data indicate that we have an excellent opportunity to develop this educational avenue. Funding for drought related efforts is increasing dramatically given the public’s interest in solving the looming world hunger problem. The US government, a number of international foundations and some private sector entities are making investments in drought related programs, and these investments could help fund the Training Center and other portions of the initiative. The combination of market potential and lack of completion gives an excellent potential for a consistent revenue stream for the College.

Outreach

Colorado State University, throughout its history as the state’s Land Grant institution, has been engaged in meeting the ever changing challenges to Colorado agriculture. It has done this through

Agricultural Experiment Station scientists and basic and applied mission-oriented research, as well as effective Extension programs to help put research results into practice. Agricultural extension and outreach efforts in Colorado and nationally are currently challenged by several issues, including: shrinking public extension funding, reduced support for applied research, fewer clientele, less county-level production expertise, and privatization of production technology.

In spite of these constraints, CSU must remain effectively engaged with our agricultural clientele if we are to respond to increasing demands for food production in water-limited environments. We propose the following strategies to improve the effectiveness of outreach programs at CSU: a) Maintain and enhance applied research programs to provide current and relevant information; b) Exploit modern communication technology to make us increasingly efficient in providing information to clientele; c) Strengthen relationships with commodity groups and other grower organizations to insure that we are addressing their most pressing problems so that they, in turn, continue to support our programs financially as well as legislatively; and d) Explore opportunities to share our knowledge and expertise with other countries in such a way as to help to address their production issues as well as to gain support for our own applied research and extension programs.

The science team

Agricultural water resource research, education, and outreach efforts at CSU are large; across the University over 140 faculty members are engaged in water related activities. The CAS faculty in particular is well equipped to address water related research, education, and outreach issues. They have the expertise to address both rainfed and irrigated agriculture, in a systems context, which is extremely critical in a time when water resources for agriculture are increasingly limited. The expertise base covers areas such as: genetics and physiology of plant drought tolerance; precision agriculture; water recycling and landscape irrigation; low volume irrigation systems; and dryland and limited irrigation management systems. The geographic location of CSU, as the land grant institution in a headwater state, means that CSU undergraduate and graduate students in agriculture sciences can readily interface with public agencies, private institutions and legislative initiatives. Faculty members also have relationships that extend into arid regions of the earth. In total, it reemphasizes the fact that CSU is in the ideal geographic position to address the needs of drought prone geographic areas both locally and globally. Study of Agriculture's Water Footprint is relevant, timely and impactful.

Although our strengths outweigh our weaknesses, current faculty expertise and resources are not adequate to tackle the challenges of optimizing agriculture's water footprint. Currently we are not in a good position to take advantage of the dramatically increased federal funding related to climate change and limited water supplies. Furthermore there are a number of international foundations and private sector entities making investments in drought related programs, and these investments could help fund this initiative. Together, these funding sources provide a means for CSU to address world hunger and poverty issues and be locally relevant to Colorado needs.

Scope/Audience

This initiative will impact undergraduate and graduate students, urban citizens, the farming community, the region, the nation, and the world. New curricula for our undergraduate students will better prepare our graduates for life in a more water limited world. Our systems related research thrust will help us better understand and optimize agriculture's water footprint. The Professional Training

Center will bring hands on education in dryland and limited irrigation systems to local, national and international professionals and scientists. Colorado citizens will be better served by a revitalized outreach program in water conserving systems.

Evaluation of success

The measures of success will be: a) increased student enrollment; b) increased grant funding; c) an established Professional Training Center; and d) increased clientele use of methods to optimize agriculture's water footprint.

Resources needed

Although we have much personnel strength at CSU and in the neighboring states, we lack the resources to carry out the research, education, professional training, and outreach goals we have proposed.

To establish the "Optimizing Agriculture's Water Footprint" initiative it will be necessary to redirect the time of two tenured CAS faculty members. Entry level faculty are unlikely to have the required experience in interdisciplinary research, and experienced faculty from elsewhere would not have the required knowledge of the CSU system or of regional agricultural systems to have immediate success.

While redirecting faculty has the benefits implied above, there are costs and risks to the redirected faculty's individual programs and to their home departments. These should be addressed as follows:

During the time that the redirected faculty members are working on the "Optimizing Agriculture's Water Footprint" initiative they should be provided program support in the form of a college funded research associate and associated operating expenses. This mitigates the risk of participating in the initiative and allows the redirected faculty to either maintain their current research programs or to develop new programs contributing to the Optimizing Agriculture's Water Footprint initiative.

The redirection reduces mission-related resources in the home departments, which can be compensated by hiring a junior faculty member to replace the redirected teaching, research and outreach effort. The job descriptions of the new hires should parallel those of the redirected faculty.

Undergraduate Curricular Innovations

We will engage undergraduate students in the strategic programs of the College and thereby increase awareness of the new and exciting opportunities in agriculture. This endeavor will also be used as a student recruiting tool. We will repackage existing courses to parallel the strategic initiatives. Courses will be arranged into 16-21 credit clusters emphasizing STEM disciplines. The newly created course clusters will be accompanied by laboratory and field research, undergraduate research experience -- all focused on awareness of food systems and environmental impacts. The importance of undergraduate research experience cannot be over emphasized in this strategy. Examples of program clusters for coursework include: Biomedical Agriculture, Environmental Economics, Food Safety and Security, Food Systems, Meat Processing, and others. Program clusters that are successful will be submitted for formalized degree status.

Two distinct target groups will be attracted and served using this strategy. The first target includes students in existing Track II Honors programs, which are discipline-oriented curricula of 16-17 credits. Individual programs may include courses up to the graduate 500-level, undergraduate research experience, and a professional paper. Academically, Honors students are highly qualified, particularly in the STEM disciplines, which fit well with our strategic initiatives. The second target includes the non-Honors students, who would be encouraged to participate in research without the formality of the Honors program. Because undergraduates would be working directly with faculty as well as graduate students, they become immersed in a professional, scientific-based environment. The graduate-undergraduate student connection could be formalized into a mentor-mentee relationship providing insight for both students. Graduate students would receive initial training allowing them to be more effective in guiding undergraduates.

As the University and the College introduce new curricular opportunities, we also need to respond to the growing numbers in existing programs such as Agricultural Education. Our Agricultural Education graduates teach at the K-12 level in rural and suburban areas of Colorado and surrounding states. These graduates are training the next generation of practitioners in the art of agriculture. This program is vital to the future and success of agriculture. Currently we have one faculty member that teaches multiple classes and seminars in fall and spring terms as well as the summer. She advises all undergraduates, double majors, and graduate students, and is the coordinator for the program. We have grown beyond one person's capacity to manage the program; obviously we need to increase faculty numbers in Agricultural Education.

We will maintain strong relationships with state Community Colleges. Working closely with Colorado State Admissions we have created guides allowing seamless transfers for community college students continuing their education at Colorado State. We are continually working to enhance our relationships with community colleges. Key strategies include distance education programs, continuing education, and national programs such as Ag IDEA; all of which benefit from increased development of on-line courses. Increased IT support is needed to assist faculty as they build online courses.