

SYSTEMS ASSESSMENT OF WATER SAVINGS IMPACT OF CONTROLLED ENVIRONMENT AGRICULTURE FORAGE PRODUCTION

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SUMMARY

The purpose of this talk is to follow up on the presentation by Dr. Gallegos and give you an idea of what we're doing at Sandia on Controlled Environment Agriculture.

This project intersects two areas of strategic interest for Sandia. The first is assuring water and agricultural safety, security and sustainability as a matter of national security. The second is contributing to the accelerated development and application of smart networked Sense, Decide, Act, and Communicate (SDAC) systems to enable transformational capabilities in sensing, situational awareness, and response for national security and other dual-uses. The project addresses both interest areas by applying networked SDACs to facilitate assessment of the dramatic water savings impact of Controlled Environment Agriculture (CEA) for forage production in arid regions. Experimental investigations and systems analyses will be conducted to understand and quantify operational and technical system performance, forage quality, optimization potential, and overall viability. Experimental studies will be facilitated and enhanced by the use of wirelessly networked SDAC systems capable of providing a more adaptable and higher-density spatial distribution of multi-modal sensing capability than would otherwise be possible or practical. The challenge and opportunity is whether CEA can contribute more broadly to water and agricultural security & sustainability through improved systems understanding & design, adoption of improved technologies & methodologies, performance optimization, and advent of better decision-support tools. The proposed project will begin to address this by quantitatively investigating the operational performance of CEA for forage production. Emphasis on forage makes sense for several reasons. Irrigated forage crops are the major consumer of water in New Mexico and elsewhere in the region. Expanding livestock forage production worldwide is putting increasing strain on agricultural land and water resources. CEA offers orders-of-magnitude savings in required water and land usage. Forage provides an experimental advantage because the crop production cycle is rapid (typically 10 days), thereby allowing multiple crop cycles in much shorter time than possible with other crops. Project results and experience will extend to other higher-value CEA applications.

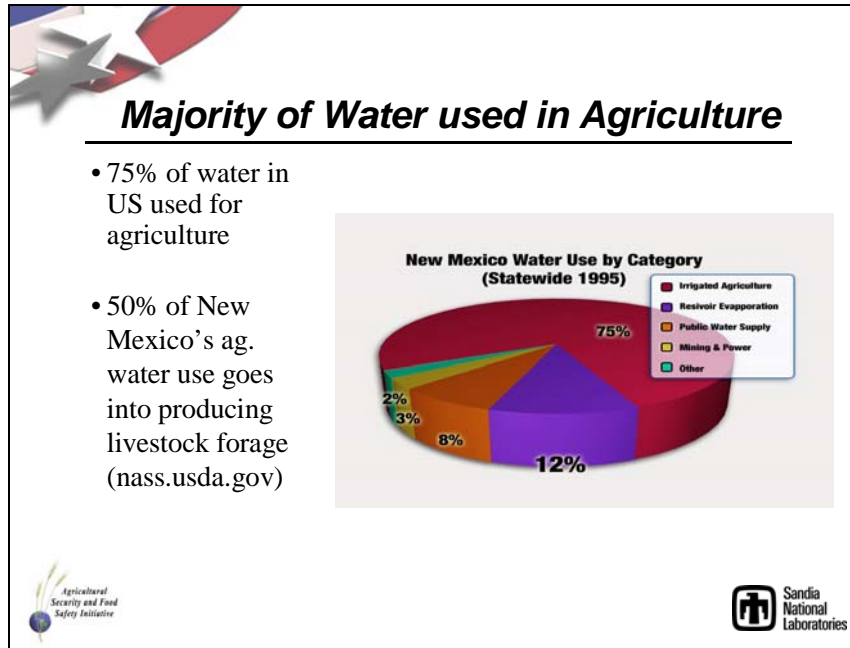
We are studying water conservation and livestock forage production in a greenhouse designed by Chihuahua hydroponic experts. Using wireless sensors, nutrition analysis and modeling and simulation, we hope to better understand and optimize the system. The work is in the spirit of the BiNational Sustainability Laboratory and located at the Santa Teresa Cattle Crossing on the U.S./Mexico border. Our ultimate goal is to provide viable technology for water conservation in agriculture for this and other arid lands of the world. Partners sharing this goal are desired.

A range of factors and issues come into play when CEA is considered from a broad systems perspective. This project will be limited in scope to initial experimental investigations and analyses of a portion of the parameter space for a selected CEA forage production system, and will focus on addressing, quantifying, and documenting the following:

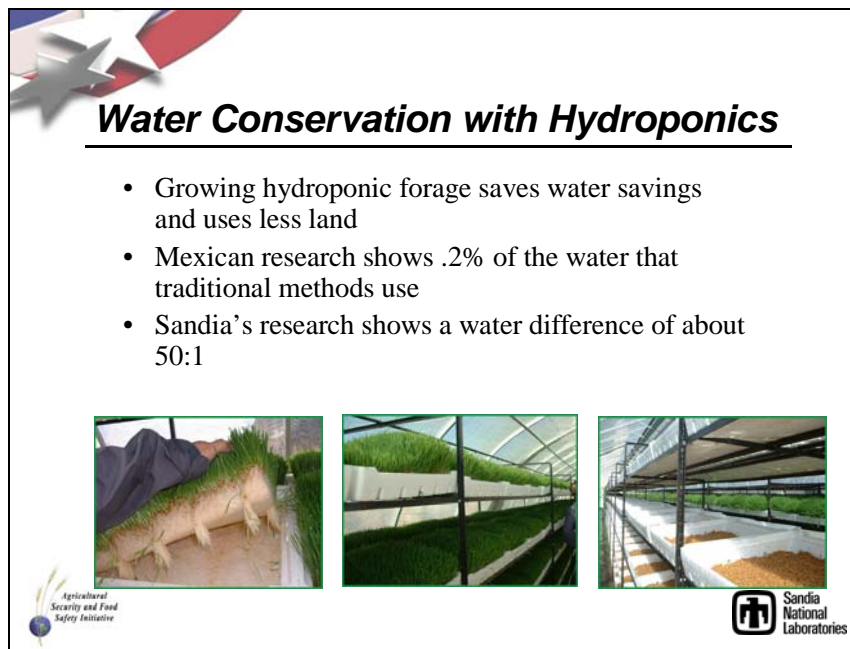
- Interdependency and sensitivity of key time- and location-dependant CEA and crop cultivar parameters:
 - Photosynthetically-Active Radiation (PAR)
 - Temperature (T)
 - Relative Humidity (RH)
 - Water and nutrient application (WN)
 - Cultivar nutrition content vs. local CEA conditions (PAR, T, RH, WN) and crop growth duration.
- System input and output flows (seed, water, nutrients, energy, labor, forage product);
- System performance and costs, including productivity and water usage per unit land area;
- Forage product nutrition content and suitability for livestock versus cultivar type;
- Thermal management and cultivar growth tradeoffs of shade screen vs. spectrum modifying film glazing.

CEA forage production demonstrations are currently underway in Estancia and Albuquerque, New Mexico. The research described here will be conducted in a CEA forage production facility being established in Santa Teresa, New Mexico. The facility is a cooperative demonstration effort involving agri-business stakeholders


in New Mexico interested in exploring this forage production approach. The facility consists of a forage production system based on a design pioneered in Chihuahua for growing livestock feed (Figure 2). The unit serves as the test bed for monitoring dynamic CEA/cultivar system operational performance and conducting thermal management tradeoff experiments.



Since this is a water meeting, the place to start is with the fraction of water that is used by different sectors of the economy in New Mexico. One additional fact of all the water use is that half of the water used by agriculture goes into producing livestock forage such as alfalfa or corn for silage.







The concept is simple and in our best estimation, has a water use difference of 50 to 1. Of course, we were introduced to this technology by Hector Leon Gallegos in Mexico.



Seed Preparation

- Seed (corn, barley wheat, or sorghum) placed in recyclable trays and germinated
- Nutrient solution is applied to the roots following sprouting

The initial step is seed preparation, where the appropriate seed is soaked first in a chlorox solution then rinsed and soaked over night. Following this, the seeds are spread onto the trays as seen her in Ross' Gardens in Estancia.



Grass Growth


- Grows more quickly in hydroponics system
- Forage ready to feed in 7-10 days
- Goal is for every drop of water go to the plant













The grass growth is done in 8 to 10 days and the goal is to contribute as much water to the plant as possible.




Application

- Provides nutritious forage at fraction of the water cost
- No nutrition wasted - Cattle consume stems, leaves, roots and seed remains
- Consistent, high quality forage produced daily
- Fewer incidents of disease

The applications are for livestock including sheep, cattle, chickens and others. The entire plant is fed to the animals, roots and stems.



Controlled Environment Agriculture



Advantages of CEA:

- Higher productivity w/ less water
- Uniform crop production
- Year-round production season
- Greater overall surety (Safety, Security and Reliability) of food supply
- Modular and scalable
- Siting independent of agricultural quality of land

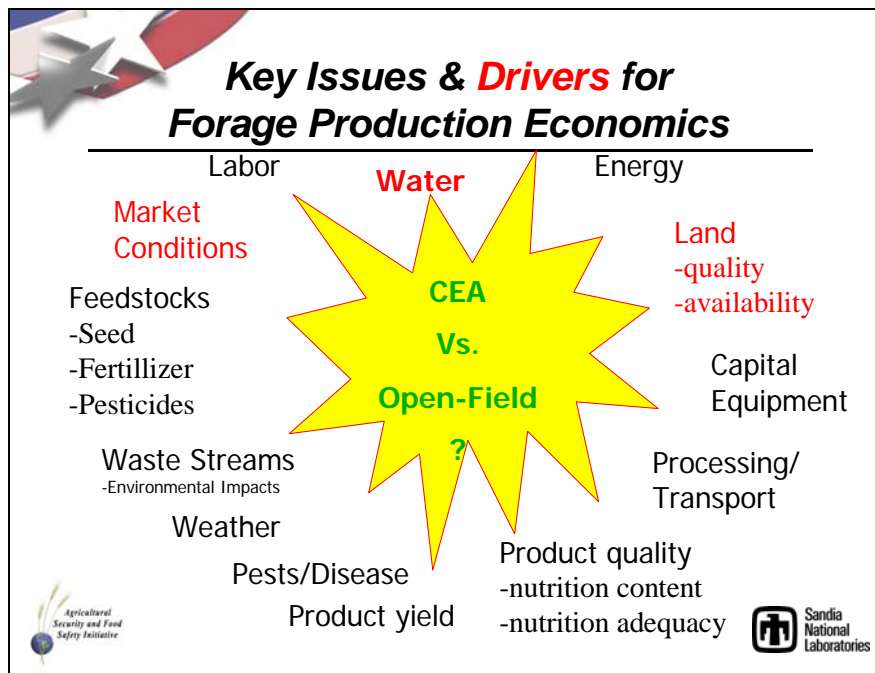
Challenges in exploiting CEA:

- Capital & operations costs
- Labor intensive
- High tech operations require more training
- Low tolerance for operational errors
- Socioeconomic, educational, and cultural issues
- **Potentially disruptive**

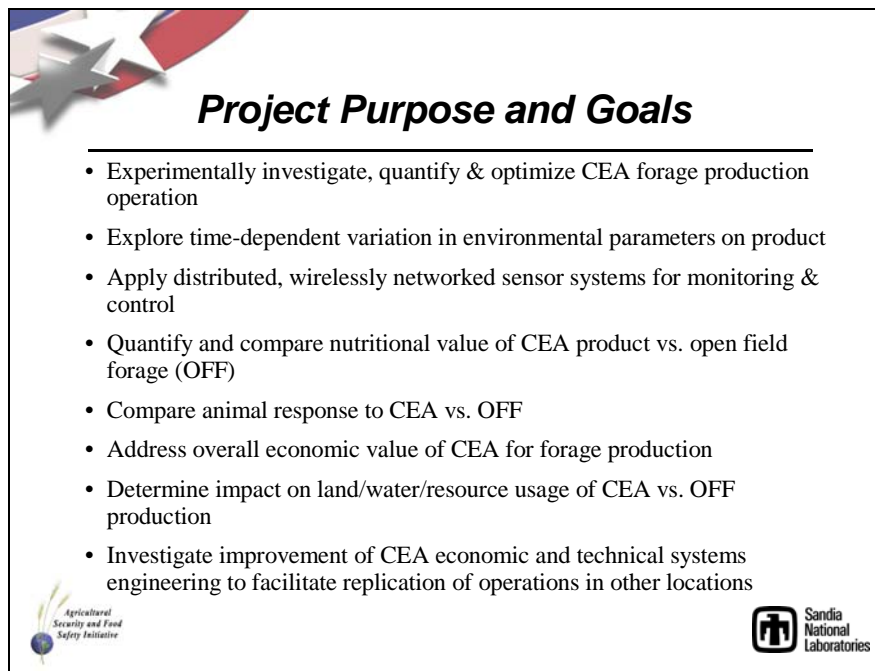
CEA

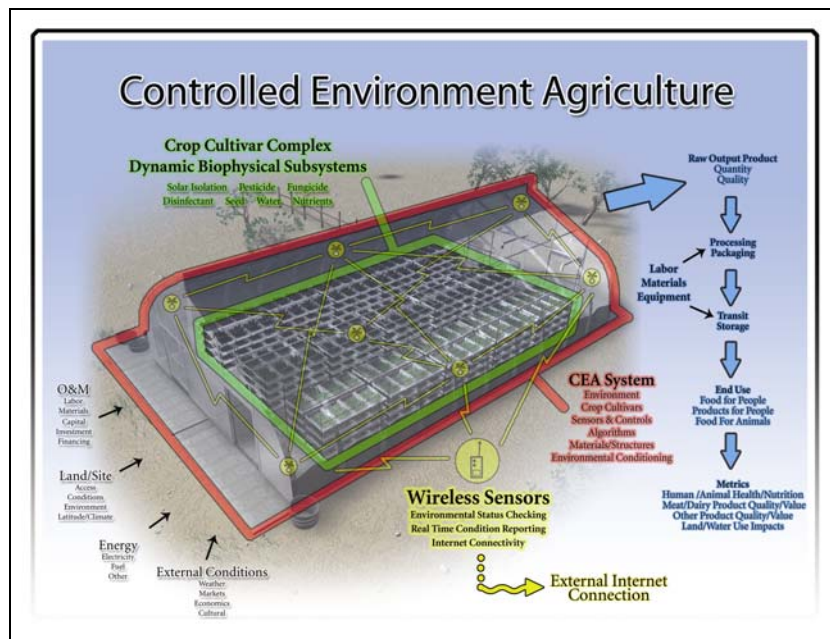
The advantages of CEA is that one can achieve year round production, get higher productivity with less water use and have a more uniform reliable forage supply. The disadvantages are that it requires more capital and operating costs, has a low tolerance for operational errors and has socioeconomic, educational and cultural issues associated with it.



The key issues and drivers for demonstrating the CEA forage production economics are listed here. A key driver for the ultimate adoption of the technology could be in the water area, where a person with water rights may sell that water for a given price and receive ample money for investing in CEA.




The purpose of this project is simply to investigate the forage production operation as described by Hector Gallegos and to compare the efficacy of this to open field forage productions. The use of wirelessly networked sensor systems for monitoring and control will be done along with an evaluation of the impacts this technology can have on land, water and resources.




A schematic of the CEA project is given in this diagram, where the issues and drivers are listed along with an indication of the remote monitoring capabilities.

Why Forage Production?

- Rapid (8-10 day) crop cycle: A “fruit fly” analog for CEA study
- Provides convenient experimental system for quantitative CEA investigations *and* immediate animal response
- Major agri-business product *and* water user in New Mexico and other desert regions
- CEA forage production could have:
 - Positive impact on agri-business community & economic development
 - Huge positive impact on broader regional water use
- World Bank projection over next 20-years:
 - Livestock development to be about 30% of global ag output value
 - Will directly use 80% of world’s agricultural land surface
 - Will represent >2/3 ag-sector water consumption



Agricultural
Security and Food
Safety Initiative

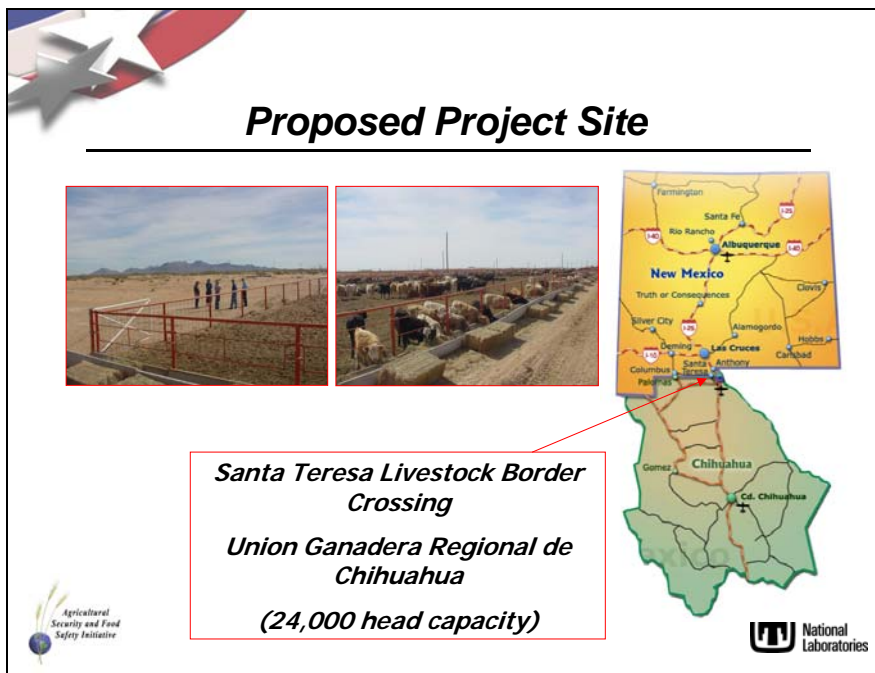


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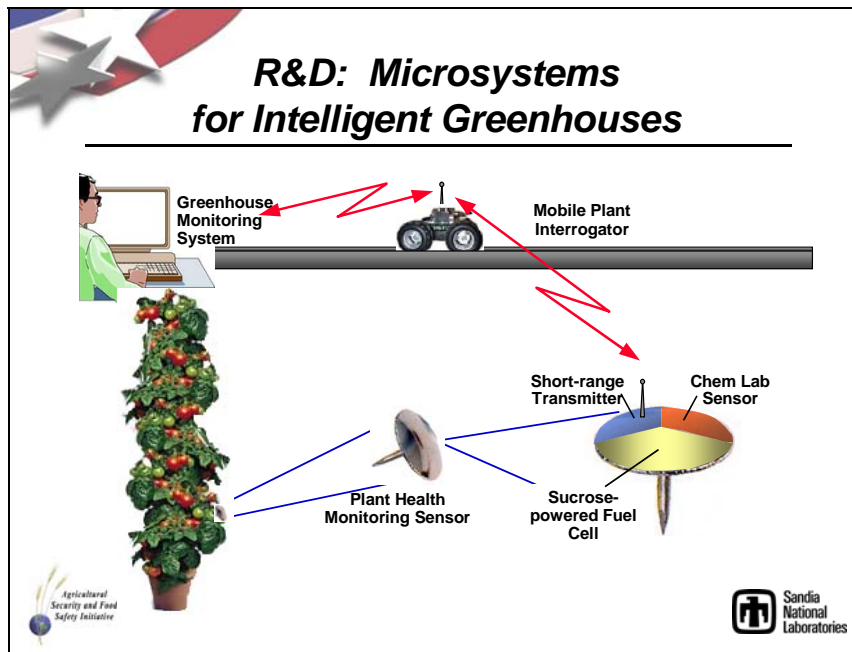
Forage crops are produced rapidly (1-to-2 week rotation), thereby providing a convenient crop system for the study of CEA environment/crop dynamic interactions and development and testing of improved sensing, modeling & simulation, and systems control techniques, i.e., forage is the “fruit fly” analog for initial CEA studies.

Forage production is a major agri-business product and water user in the State of New Mexico (and Chihuahua?). If CEA forage production can be optimized and made economically viable, this could have not only have a positive impact on the agri-business community, but also have a major impact on broader regional water and land use.

The World Bank is projecting that livestock development will soon constitute about 30% of global agricultural output value, and directly or indirectly use 80% of world’s agricultural land surface and significant agricultural water consumption... with serious implications for the environment, resource availability, global food security, rural economic development, etc.



The project site is at the Union Ganadera Regional de Chihuahua in Santa Teresa, NM. The number of cattle that cross the border at this location is huge and the opportunity for placing a greenhouse on the east end of the corals (shown above left) has been granted by the Northern Chihuahua Cattlemen’s association.



One of the long term goals is to incorporate as much of the high tech capabilities at Sandia into the greenhouse operation. Here is shown a plant monitor that is able to use the plant’s sucrose for power, sense the plant health and transmit this to a mobile receiver and ultimately to a system that looks at the entire greenhouse.



Beyond the *“Green Revolution”*

- Develop **Controlled Environment Agriculture (CEA)** technologies, systems, operations, and crop biophysical interactions
- Develop and maintain **Contextual Awareness**: integrate CEA technologies and practices within social, economic, educational, cultural, and historical context
- **Multi-disciplined collaborative teams** in science & technology, economics, agri-business, socio-economic/cultural

Scope & Progression of Applications

- Forage Production (preliminary CEA investigation)
 - High-Value Horticultural Crop Production
 - Nutraceuticals & Other GM cultivars



*Increasing:
Product Value (\$), Quality Control, & Security*





Our ultimate vision is to develop CEA technologies, contextual awareness and do so with multidisciplinary research teams. The progression of applications should flow from forage production to high value horticulture and finally to nutraceuticals that would fully utilize Sandia’s investments in bioinformatics, modeling and simulation and nanotechnology.