Resilient Southern Plains Agriculture and Forestry in a Varying and Changing Climate

Conference Report

July 18-19, 2017 | El Reno, OK

Texas A&M AgriLife

USDA United States Department of Agriculture Southern Plains Climate Hub

Kansas State University

Oklahoma State University

Table of Contents

Executive Summary

In July 2017, the conference, *Resilient Southern Plains Agriculture and Forestry in a Varying and Changing Climate*, reviewed the status and needs for the future in the Southern Plains relative to irrigation and dryland farming, range and livestock, confined animal feeding operations (CAFOs), and forestry. The conference was at the Redlands Community College in El Reno, Oklahoma in conjunction with the U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS) Climate Hub. Participants included stakeholders, researchers, and extension faculty as well agencies' representatives.

Conference attendees agreed that the climate outlook is greater variability with positive and negative expectations for pests and diseases. Major themes included: increased diversification to maintain the local economies over the next several years resulting from the mining of the Ogallala Aquifer; irrigation evolution to dryland crops or pasture production; and a strong need to protect the rangeland resources of the region. For CAFOs the major concern was locally produced feed, particularly forages.

The conference was structured into two main components. The first — assessing the current state of knowledge — centered on seven white papers written by regional experts: Climate Considerations; Food and Fiber Production Systems; Range, Grassland, and Livestock Management; CAFOs; Forestry, Arthropod Pests and Plant Disease; Economic Drivers. Formal presentations of these papers served to outline the status, challenges, gaps, and opportunities for production agriculture across the Southern Plains within the context of climate extremes and changes. The second working component — understanding and prioritizing science and service requirements — utilized breakout sessions where scientists and stakeholders identified challenges and opportunities to mitigate climate-driven production risks for regional agriculture. The goal was to take an optimistic view by identifying resources and capacities that exist in the Southern Plains to address those challenges, including proactive, cross-boundary research and extension team development. A roadmap for future research and extension will be developed based on the conference.

Introduction

Agricultural production in the U.S. Southern Great Plains is extensive and diverse. The region is home to numerous cropping, livestock, and forestry systems, which serve as vital economic components for the Southern Plains states of Kansas, Oklahoma, and Texas. These systems, while mature and resilient in many respects, are nonetheless at risk from the ongoing impacts of climate extremes as well as the projected impacts of future climate change. As scientists and extension professionals continue to refine their understanding of how climatic extremes and changes will affect agriculture in this region in the future, there is a concurrent need to understand the critical elements and commonalities among production systems regarding those risks, as well as the information requirements and regional capacity needed to harden production systems, improve resiliency, and enhance profitability.

In view of this challenge, the *Resilient Southern Plains Agriculture and Forestry in a Varying and Changing Climate* conference was convened July 18-19, 2017 in El Reno, Oklahoma. The conference was jointly organized by Kansas State University (KSU), Oklahoma State University (OSU), Texas A&M University (TAMU), and the USDA Southern Plains Climate Hub and hosted by Redlands Community College. It served as a platform for assessing the current understanding of how climate variations and changes affect Southern Plains agriculture and for prioritizing research, extension, and education needs consistent with that understanding. Approximately 80 attendees representing federal, academic, extension, and producer and commodity perspectives participated in the 1.5-day event.

The conference was structured into two main components. The first — assessing the current state of knowledge — centered on seven white papers written by regional experts: Climate Considerations; Food and Fiber Production Systems; Range, Grassland, and Livestock Management; CAFOs; Forestry, Arthropod Pests and Plant Disease; Economic Drivers. Formal presentations of these papers served to outline the status, challenges, gaps, and opportunities for production agriculture across the Southern Plains within the context of climate extremes

and changes. The second, working component — understanding and prioritizing science and service requirements — utilized breakout sessions where scientists and stakeholders identified challenges and opportunities to mitigate climate-driven production risks for regional agriculture. The goal was to take an optimistic view by identifying resources and capacities that exist in the Southern Plains to address those challenges, including proactive, cross-boundary research and extension team development.

This report, assembled by the conference organizers and structured around these two main conference components, is intended to serve multiple purposes:

- Provide an overview of agriculture in the Southern Plains and the overarching factors impacting production systems.
- Summarize the current state of knowledge regarding climate-driven risks on regional agriculture.
- Identify high priority science questions, research needs, and extension programming necessary to mitigate climate risks in Southern Plains production systems.
- Highlight existing regional capacity and resources available to address those risks.
- Present opportunities for federal agencies, land-grant universities, the private sector, and others to address critical, science-based issues regarding climate and agriculture in the Southern Plains.

In addition, this report serves as a first step in outlining a 10-year research and extension roadmap for climate and agriculture in the Southern Plains. The roadmap will consider key drivers of production risks in the region, the potential for technological advances and new management strategies, changes in policy and education, and the potential for greater development of integrated systems approaches to production agriculture.

Description of the Southern Plains

Kansas, Oklahoma, and Texas are three of the largest agriculture-producing states in the U.S. The food produced in the region is essential to national and international food security. Projected climate change will increase the challenges of agriculture in the region and will require significant investments in research and extension. This region is a world leader in beef, wheat, grain sorghum, cotton, and corn production and is rapidly increasing production of dairy and swine. Crop production includes both rain-fed and widespread irrigation from the High Plains/Ogallala Aquifer.

This region is characterized by extreme diversity in climate with annual rainfall ranging from 50 inches on the region's eastern side to as low as 10 inches in the semi-arid western region. There is also great variability in rainfall from season to season leading to frequent droughts and flooding. Southwest Kansas and the Texas and Oklahoma panhandles were the region's most adversely affected by the dust bowl years of the 1930s and droughts of the 1950s and 2010s. In addition, the region experiences hot summers and cold winters.

Irrigation from the Ogallala Aquifer makes this region one of the most productive regions in the U.S. for growing alfalfa, cotton, corn, wheat, sorghum, and soybeans. These crops provide cattle operations with feed for the large feedlot cattle industry. The success of large-scale agriculture in areas of inadequate precipitation and lack of perennial surface water for diversion has depended upon pumping groundwater for irrigation. Farmers and ranchers began intensive use of groundwater for irrigation in the 1930s and 1940s. In many areas of the aquifer, especially the southern portion of the Texas High Plains and northwestern Kansas, the saturated thickness has been reduced by as much as 40% of pre-development levels. Withdrawals greatly exceeding recharge rates have resulted in deeper water tables, reduced saturated thickness, and lower well yields. By 1980, water levels in the aquifer in parts of Texas, Oklahoma, and southwestern Kansas had declined more than 100 feet, and by the late 1990s in certain areas of Texas and Kansas, farmers already abandoned irrigation due to inadequate well yield and cost to pump. Average water level changes in the Ogallala Aquifer from predevelopment to 2007 by state were: Kansas, -22.3 ft; Oklahoma, -12.8 ft; and Texas, -36.4 ft. Water level declines increase pumping costs and decrease well yields. Water level declines also negatively affect surface water flow in some cases.

Soils in this region are among the most productive in the world. In 2016, total agriculture land in the three states was 210 million acres, or 23% of the entire U.S. farmland. Kansas farmland totaled 45.9 million acres (3rd largest agricultural state), Oklahoma 34.2 million acres (7th largest agricultural state), and Texas 129.8 million acres (largest agricultural state in the U.S.). Agricultural lands were split between cropland and grazinglands with cropland consisting of 51%, 29%, and 17% of the total agricultural lands in Kansas, Oklahoma, and Texas, respectively. The states have extensive irrigated cropland totaling 7.8 million acres.

In 2012, cotton was grown on 6 million acres (value, $3.2 billion), corn on 8.4 million acres (value, $3.5 billion), grain sorghum on 5.4 million acres (value, $1.14 billion), hay on 10.4 million acres ($2.36 billion), soybeans on 4.7 million acres (value, $1.97 billion), and winter wheat on 18.5 million acres ($2.29 billion). Total crop production value in 2012 was $16.3 billion. Kansas, Oklahoma, and Texas were the three leading winter wheat-producing states; Kansas and Texas were the leading grain sorghum producing states; and Texas was the largest producer of cotton and hay.

Due to favorable weather and abundant feed supplies, livestock production is a major industry in the three-state region, with total sales of $34 billion in 2012. Texas, Kansas, and Oklahoma were the first, second, and sixth largest producers (by market value) of cattle and calves in the U.S. (2012). Due to the favorable climate in the Southern Plains, the region has evolved into a major region for feedlots and dairy production, creating jobs and economic activity, which contribute to the viability of rural communities.

Total forested area in the region is 78.1 million acres, which is 29.1% of the total land area (264.7 million acres). A discrepancy in acres of agriculture land and forestland is that forestlands include some grasslands, resulting in double counting. Of the two primary forest groups in the 78.1 million acres, timberland (i.e., land suitable or managed for traditional wood producers) comprises 21.7 million acres and woodlands make up 56.4 million acres in the region. Nearly 65%, or 14.2 million acres, of the timberland is pine forest. Of the forest resources in the region, 70% are held by non-industrial, private owners (termed: family forest landowners); 20% are held by industry; and 10% are held in public ownership (federal, state, or municipal). More than 202,000 family forest landowners have timberland holdings greater than 10 acres in the region, and nearly 298,000 landowners have woodland holdings of less than 10 acres in the region.

The lumber and wood products industry in the region annually produces $22.6 billion in direct output and nearly 80,000 direct jobs, paying more than $4.4 billion in wages annually. If considering indirect economic impact, the lumber and wood products industry in the region annually contributes $39.1 billion, and 172,000 jobs paying $9.6 billion in wages. These values do not include the significant economic contribution of forests, both direct and indirect, to recreational activities (hunt-

ing, fishing, hiking, comping, ecotourism, etc.). Forest in the region also provide ecosystem services essential to the health and well-being of the people living in the region. For example, forests in Kansas, Oklahoma, and Texas store 2.2 billion tons of carbon that could be valued at more than $48 billion. Water resources are crucial because approximately 80% of the region's freshwater resources originate on forestland. Healthy forests are also crucial to watershed regulating services (i.e., capture, filtration, and regulation), which is conservatively valued at more than $13 billion annually in Texas alone.

In addition, this region has significant infrastructure related to transportation, enhancing the movement of agricultural products. There are interstate highways traversing the region, strong railway facilities and major air support. Beneficial transportation combined with strong education, research, and extension programs of land grant universities, plus a system of higher education related to agriculture, provides the basis for unleashing science to take us into the next century with a highly viable agricultural economy.

Overarching Factors Impacting Agriculture and Forestry

The Southern Great Plains offers unique opportunities and challenges for the future of agriculture and forestry. Many factors are very broad and touch all facets of developing a roadmap of research and extension directed at assuring resilient agriculture and forestry sectors, including meeting environmental and economic goals. This section highlights just four of these overarching factors: climate variability/change by Dr. John Nielsen-Gammon of TAMU, Ogallala Aquifer outlook, economic drivers by Dr. John C. Tracy of the Texas Water Resources Institute, and pests and diseases by Dr. Phillip Mulder of OSU. The July 2017 conference in El Reno identified three overarching factors and for this report, the Ogallala is added. It is recognized that there are national and international forces that will have a significant influence on the Southern Plains including the 2018 Farm Bill, global trade, regulations, the political environment, labor issues, changing tastes and preferences, and the U.S. economy, to name a few.

Climate variability/change

The expertise of Dr. Nielsen-Gammon was evident in his presentation related to climate and outlook. Models and observations provide partial insight on the future related to the impacts of climate change. There is consensus of a drying trend for this region (even though average rainfall may not be all that different from the past, the incidence could be dramatically impacted), and likelihood of a temperature rise overall, suggesting an increasing demand for water. It is the uncertainty of the future related to climate that further necessitates a proactive approach to the future of agriculture and forestry in this region.

Ogallala Aquifer outlook

It is clear that, for the most part, the Ogallala Aquifer in Kansas, Oklahoma, and Texas is being depleted. Although it is a huge aquifer that stores vast quantities of water, the water level continues to decline. This results in falling well yields in gallons per minute as well as greater lift and associated cost to bring the water to the surface. There are several research and extension projects directed to address water conservation from the Ogallala and across the Southern Plains overall. Over time, irrigation has evolved from flood or gravity flow to highly efficient distribution pivot systems as well as an increasing number of drip systems. These actions are combined with management strategies for optimal application of cropping systems and irrigation decisions. Nevertheless, it is essential to plan for a future where the level of irrigated acres will continually decline leading to dryland (rainfed) crop production or, in some cases, range and livestock production. This transition is a critical challenge to the future of the region with serious implications for the overall local economies.

Economic drivers

Closely related to the future of the Ogallala Aquifer is the economic drivers and future of rural communities as discussed by Dr. Tracy. Agriculture in general and in particular, irrigated agriculture, is the economic lifeblood of many rural communities. Already there has been some stagnation within rural communities trending toward larger integrated farming and ranching operations with less reliance on input dealers and service providers. Rural communities are a driving force across the Southern Plains providing for social structure, education, and local government. What lies in store for rural communities of the Southern Plains and what are the options for maintaining a strong community structure?

Pests and diseases (animals and plants)

Dr. Mulder developed insight on potential issues for the Southern Plains that include plants and animals, resulting from climate variability/change. Naturally, there are more questions than answers, but factors such as potential immigration and emigration, survival of pests, overwintering impacts, outbreaks, and even beneficial impacts are all open questions.

Conference Outcomes

The El Reno conference had goals to bring together scientists and stakeholders to (1) gather the best available information related to the impacts of climate change for agriculture and forestry across the Southern Plains through seven white papers, (2) organize breakout groups across four major groupings — irrigated and dryland crops, range and livestock, confined animal feeding operations, and forestry — to identify the most relevant research and extension needs over the next 10 years to have resilient agriculture and forestry systems. Across these four topics, the overarching issues above were presented.

Science Questions and Research Needs

This exercise was successful in identifying gaps in knowledge with associated science-based questions and research needs. A basic gap exists related to uncertainty and the direction of climate change with the expected impact. This led to questions about the region's future related to pests and diseases for plants and animals. Productivity in light of a changing environment is an unknown. What are viable futures for rural communities? What are the most vulnerable economic sectors? How do we go about developing alternative opportunities?

Existing Resources and Regional Capacity to React

The Southern Plains has a strong base of scientists and on-going research programs. There are land grant universities, other universities addressing agriculture and forestry needs, federal and state agencies, strong commodity organizations and political support.
Ongoing projects/programs:

- Ogallala Aquifer Program with ARS, KSU, Texas Tech University (TTU), West Texas A&M University (WTAMU), and TAMU
- USDA-National Institute of Food and Agriculture (NIFA)-funded Ogallala Coordinated Agriculture Project (CAP) (Colorado State University [CSU], KSU, TTU, OSU, New Mexico State University, University of Nebraska, TAMU)
- Grazing CAP (KSU, OSU, University of Oklahoma [OU], Tarleton State University, ARS, Noble Research Institute)
- Oklahoma Established Program to Stimulate Competitive Research (EPSCoR)
- Foundation for Food and Agriculture Research (FFAR) where there is development of an irrigation center of excellence — in preparation including Southern Plains
- Research and extension programs at land grants and other agriculture universities
- Experiment station research
- Extension service programs
- State water resource centers
- Value of off-campus research and extension facilities
- State and federal agencies and associated funding programs
- USDA-NIFA forthcoming RFP for integrated proposals
- ARS Climate Hubs
- Natural Resources Conservation Service Conservation (NRCS) Innovation Grants
- ARS Long-Term Agroecosystem Research
- National Science Foundation – Innovations at the Nexus of Food, Energy and Water Systems
- Foundations such as the Noble Foundation
- Commodity organizations with check off resources funding projects

Addressing the Opportunity

Proactive team building

A key to having successful research and extension programs adopted involves being inclusive, which means multistate and interdisciplinary. Kansas, Oklahoma, and Texas boast a history of working collaboratively and sharing freely to accelerate progress. With significant on-going programs, a major goal is to be synergistic with current research and extension programs. Part of team building includes working with agencies and funding entities in assisting with setting priorities. Furthermore, focusing on emphasis areas (water, forestry, rangeland, soil health, etc.) is an additional priority goal. The process of team building to address Southern Plains challenges and opportunities began at the El Reno conference.

Tracking funding opportunities

In the near future, broadly funding opportunities and RFPs (NIFA-integrated programs, for example) will be identified and distributed across all agencies and universities.

Not only will the scientists involved continue to develop relationships with foundations and commodity organizations, but all will reach out more to the private sector. This effort suggests additional collaboration not only with the grants and contracts offices of agencies and universities but also, and more importantly, with funding groups to gain insight of potential opportunities before a RFP is released.

Developing a 10-year research and extension roadmap

Based on information from the El Reno conference, planning documents of federal and state agencies and agriculture universities, and priorities of granting agencies, foundations, and commodity organizations, a 10-year research and extension roadmap will be developed to address the four major topics of range and livestock, CAFOs, irrigated and dryland cropping systems, and forestry. There will be merging across these topics. In the process of developing this research and extension roadmap, stakeholders as producers, processors, and organizations will bring forth the issues before them, which will be incorporated into the roadmap. Opportunities for cooperation across states, agencies, and organizations will be identified.

Conclusions and Reasons for Optimism

Infrastructure

This is a region blessed with significant infrastructure. With major roads such as interstates, paved farm-to-market roads and U.S. and state highways along with rail, there is the ability to move huge volumes of materials into and out of the region. Air transport is also strong with major airports and airlines. Additionally, the energy sector is strong where wind-based electricity is growing at a great rate and marketed throughout Texas. Solar-powered energy is in its infancy but with plentiful sunshine, even in the winter months, it can be expected to be grow. To accommodate energy generation, major transmission lines are needed to move the energy to high demand centers. All of these options offer employment. Energy, processing, tourism, and services are a giant opportunity for the diversification of the economy.

Research and education

Throughout the Southern Plains is a most impressive research, education, and extension network. Each state has a land grant university, research programs, extension programs, and state and federal agencies with well-respected scientists, which strengthen on-going partnerships across agencies and universities. Expertise among participants ranges from climate studies to engineering to crops and livestock to forestry, economics, ecosystems, recreation and tourism, human behavior, and much more. There are excellent modelers who can apply models to project possible outcomes of alternatives. Demonstrated across the region is a level of excellence as represented through the successful awarding of competitive grants. Indeed the outlook is optimistic with the talent available.

Resources

This is a region with great pride in its resources. There are examples of restoring and protecting soil health in crop production as well as range. The farmers are very quick to adopt new technology that can lead to improved water conservation. There is evidence that the per capita water use by cities is declining. Farming operations such as minimum and no-till that preserves both soil and moisture have been adopted. There is an appreciation for ecosystem services coming from the land and water.

Gaps, Needs, and Challenges

For the conference, white papers were developed for each of the seven topics, and outlined the topics, indicated challenges, and identified gaps and needs. This section is an abbreviated discussion of the needs as identified by the authors. This includes Climate Considerations; Food and Fiber Production Systems; Range, Grassland, and Livestock Management; CAFOs; Forestry; Arthropod Pests and Plant Disease; Economic Drivers. The white papers are listed in the appendix as well as available on the El Reno website (http://twri.tamu.edu/el-reno). The authors of the white papers are commended for their dedication on developing, in a limited number of pages, the basic issues and needs.

Climate Considerations

The combination of known and projected climatic factors indicates a semi-permanent drying trend for the Southern Plains, but droughts are so erratic that a clear trend has not emerged. Projections of future drought severity rely on computer models, and it is also difficult to capture all the nuances of drought in a single metric. Different agricultural commodities are sensitive to different types of drought at different times of the year. Drought projections have not been made to that level of specificity nor can scientists be confident in such projections unless the projections are consistent with observations and across models. In addition to observations related to drought, many suggest a drying trend for the Southern Plains associated with climate change while others suggest annual rainfall may not be significantly different but occurrence may shift. While it seems plausible that other forms of severe weather, such as tornadoes, hail, and hurricanes, may behave differently in a warmer climate, neither observations nor models provide conclusive evidence on trends in frequency or intensity of severe weather events. Projections of these important details of climate change, as well as its overall magnitude, are likely to continue improving as observational evidence increases and computer technology advances. OU and KSU scientists are also finding that rather than long-term droughts and wet periods, we are seeing more short-term droughts and wet periods, resulting in more wildfires and more difficulty in planning for agricultural production.

Arthropod Pests and Plant Diseases

Research has concluded that global warming will likely increase abundance and occurrence of insect pests and plant diseases in agricultural systems. Most of the evidence cited for this increase is based on either empirically derived information, simulation models developed from laboratory observations, and/or environmental extremes that resulted in pest outbreaks. While these phenomena can help explain why arthropod and plant disease problems are more pronounced during specific weather extremes, they cannot adequately account for all biotic and abiotic influences that come to bear on these populations and their accompanying regulating factors (e.g. beneficial organisms). Likewise, while it is safe to assume that insect pests generally become more abundant as temperatures increase (up to a point where environment or competition regulate numbers), the same relationship does not necessarily exist for many plant pathogens.

Continued execution of research and extension programming is needed to monitor and measure impacts of extreme weather events and climate change in a clear, transparent, unbiased, and nonpartisan manner.
Specific research gaps/needs include:

- Long-range research trials to ascertain the effects of climate changes on insect and plant disease problems, which would require long-range funding support;
- Controlled environmental trials to assess additional atmospheric changes on insects and plant diseases;
- Landscape ecological studies to ascertain how climate changes affect plant communities, herbivores (pest insects), plant diseases, and beneficial organisms;
- Economic analyses of how changes in the expansion of insect and plant disease range, overwintering capacity, generational time, etc., would impact agricultural costs and returns;
- Analysis of alternative climate change scenarios to examine their expected effects on soil-inhabiting insects and plant diseases in the rhizosphere surrounding host plants;
- Examination of the effects of rare and/or extreme weather events on insect and plant disease epizootics (e.g. immigration and emigration, survival, etc.); for example, how does a combination of such events (e.g. fewer cold spells in winter followed by drought in spring or summer) affect outbreaks; and
- Examination of how changes in carbon:nitrogen concentration ratios caused by elevated CO_2 affect plant pathogens, insects, or their plant hosts (e.g. lignification).

Specific extension needs include:

- Development of forecasting tools within the system to help producers be more proactive to changing environmental conditions;
- Expansion and use of locally based climate-monitoring systems (e.g. Mesonet) to more closely examine epidemiological data from historical records in helping improve the reliability of predictive models; and
- With an eye on future generations, development of a portfolio of social media and electronically based approaches (e.g. apps, blogs) for providing information to the agricultural sector.

Economic Drivers

Future research efforts and activities should move beyond its current focus on "more crop per drop," and increase its focus on deriving a higher economic and social value of water use across the region with the diversification of enterprises. Opportunities exist for maintaining and growing these predominately rural economies by moving to higher value crops, enhancing energy production (both renewable and non-renewable), accelerating processing of agriculture-related commodities, expanding the service sector, and taking greater advantage of tourist potential (i.e. hunting, ecotourism, etc.). The region is characterized by a strong transportation system that enhances the opportunity for economic diversity. This can perhaps be summarized as **focusing future research and development efforts on "more dollars per gallon" of economic and social value associated with the use of the declining water resources in the region.** This research could help provide knowledge and tools to individuals, decision-makers, and civic leaders associated with the agricultural and natural resource sectors to help them maximize the economic and social impact of water use across the Southern Plains in a future with declining resources through a diverse set of economic sectors.

Food and Fiber Production Systems

Throughout Kansas, Oklahoma, and Texas, crop production is a major component of the state and regional economies and the lifeblood of rural communities. There are forces at play that can be expected to impact crop production whether irrigated or dryland, including the farm bill, global economy, trade relations, energy, and climate variability/change. There is an ever-increasing economic incentive to employ economies of size (i.e., expand the size of an operation). Typically for the Southern Plains, an economically viable dryland operation is comprised of greater acreage than a typical irrigated crop production farm. With pressure to become larger for economies, the decline of aquifers, and transition to dryland, there is even more incentive to increase the size of operations. Needs related to crop production for the future include:

- Increasing capacity in plant breeding, genetics, and crop testing to identify and deploy genes for drought tolerance and pest resistance (CRSPR, molecular markers, ID genes for stress tolerance, breeding of stress-tolerant lines, high throughput phenotyping, and field testing of advanced lines);
- Increasing capacity to detect and mitigate invasive pests (IPM capacity, improvement of pest management technology including insects, disease, mycotoxins, and weeds); and
- Improving precision application of crop inputs (water, fertilizer, pesticides) to reduce crop stress and minimize external inputs (UAS, highly efficient variable application irrigation systems, and advanced scheduling technologies).

Range, Grassland, and Livestock Management

Ranches comprise the bulk of the land in the Southern Plains. Production forthcoming is dramatic, including beef (the number one in farm gate receipts in Texas), ecosystem services, recreation, and hunting. With or without climate change, there are a number of different components in the system, thus multiple research opportunities exist including the following topic areas:

- Soil health (water filtration, nutrient cycling, carbon sequestration, microbes impacting greenhouse emissions);
- Alternative grazing/management strategies (such as adaptive multi-paddock grazing under appropriate conditions);
- Forage breeding, production, and use under diverse climatic conditions;
- Plant biodiversity;
- Evaluation of adaptive response strategies to abrupt climatic events;
- Development of multi-use habitats to include wildlife;
- Assessment of the environmental impacts of beef production, grazing systems, and wildlife;
- Impact of grazing systems and forage-based beef cattle production on greenhouse gas emissions;
- Sustainability (economic, environment, social) of traditional and alternative grazing and management practices considering behavior impacts of change;
- Genetic tools and selection criteria for forage-based beef cattle production systems; and
- Forage system adaptability given long-term climatic changes and shift of cattle to higher rainfall regions.

Information and technology developed and disseminated from competent research and extension programs have historically favorable affects on the success of the beef cattle industry. Future beef production operations will face emerging challenges; as in the past, effective research and extension programming will help managers successfully meet those challenges.

Forestry

When considering traditional timber production, the Western Gulf/Southern Plains region has unique challenges. The region already experiences the hottest conditions and lowest precipitation compared to other regions with similar timber-producing species. Climate change will likely worsen drought conditions more rapidly and to a greater extent in this region. While climate change has marginal effects on productivity in the short term (50 years), greater risk to the lumber and wood product industries in the region lies with extreme weather impacts and concomitant insect, pathogen, and wildfire outbreaks. Proper and timely forest management using updated silvicultural parameters will become increasingly more important. For example, recent rainfall reduction studies indicate that the decrease in plantation growth under dryer conditions may be mitigated, at least in part, through nutritional management (i.e., proper application of fertilizer). Specific research needs include evaluating:

- Impact of invasive species on crop production and silviculture practices and updated tools and techniques to minimize/reduce their proliferation;

- Potential economic performance of forest management under future variable climatic conditions on both private and public lands;
- Baseline stand-level growth models, coupled with general response functions for thinning, competing vegetation control, and fertilizer applications to provide more accurate estimates of plantation productivity for varying levels of management;
- Site quality (site index) values to biophysical variables (soils and climate) that better associate the effects of climate in tree growth, fertilization, competition control, and thinning models;
- Scaling up of growth and site quality relationships from stand- to regional-level productivity under varying assumptions of silvicultural inputs and climatic influences;
- Above- and below-ground carbon and nitrogen pools and fluxes, and key biological and ecological modeling parameters, vary with climate, soils, stand development, and management factors;
- Pine quiescent period, now and in the future, and how it impacts planting parameters, herbicide use, and other silviculture practices;
- Vegetation control options and prescriptions, given greater climate variability, leading to improved techniques, rates, timing, and chemistry that better control unwanted plants without further stressing crop trees;
- Response of forests to carbon fertilization (resulting from increasing atmospheric CO_2) and precipitation variability;
- Suitability of seed sources for major timber-producing species to resist impacts of climate change/variability;
- Biological requirements of crop trees under changing climate variability with regard to stocking, market demands, and operational requirements;
- Impact to crucial forest ecosystem service from climate change; and
- Value of forest ecosystem services to mitigate climate change.

CAFOs

CAFOs serve as a vital business model for animal-protein production in the U.S. Due to the concentration of animals within certain regions in the Southern Plains, steps to address long-term, economical production inputs is essential in the presence of future altered weather patterns. Efforts emphasizing 1) water-resource conservation and 2) more efficient use of on-farm and related cropping systems supporting feed needs must be advanced for the long-term viability of livestock operations in the Southern Plains. Specific suggestions include:

- Feed/forages – breeding, evaluation, and demonstration of more weather- and climate-resilient feed/forage crops with reduced water requirements; improved digestibility estimates for ration formulation; integration of whole crop and livestock/poultry systems that optimize net consumption of mass (i.e., water, nutrients) and energy resources, profitability, net ecological stress, and social acceptability (i.e., nuisance potential, community relations, resource consumption, husbandry practices, cultural factors); increased acreage requirements for beneficial use of land-applied manure and wastewater on limited-irrigation or rain-fed cropping systems;
- Reduction of time on feed through genetics and nutrition;
- Facility structure designs – more advanced structural designs to reduce heat stress and to mitigate its effects on productivity; improved watering equipment to reduce drinking loss; improved capture of gas emissions in manure-storage systems;
- Shade for open lots – access the impact on growth performance; efficiency of gain; impact on well-being and comfort of the animal; identify unintended or perverse consequences of shade mandates in climatic regions conducive to overnight thermal recovery (i.e., restoration of thermo-neutrality);
- Evaporative cooling and dust control – improved sprinklers; optimized sprinkler dust-control technologies and usage protocols; reduced or improved freshwater systems; recycling of captured wastewaters and overflow drinking water; low-risk uses of treated lagoon or holding-pond supernatant;
- Pest management – improve existing control measures; new control measures amid longer warm seasons; proper use to prevent resistance for chemical control measures;
- Utility efficiency – cost effective on-site, energy-saving practices and renewable energy development;

- Genetics – selection of genetic lines more resilient and/or adaptive to heat stress; continue selection pressure on efficiency of gain to reduce feed inputs; and
- Animal health – address implications of exposure to the feeding infrastructure as well as issues related to additives in feed and antimicrobial resistance.

Potential Topics and Participants

Water (urban and agriculture), Groundwater, and Surface Water

Lead: Water resource centers (CSU, KSU, OSU, Texas A&M, ARS, NRCS)
Issues/Topics:

- Irrigation (dashboard, sensors, etc.)
- Urban (landscape with sensors, in-home, real-time meters)
- Processing (animal processing, other)
- Incentives for conservation (pricing, meters, education)
- Policy implications and alternatives (irrigation district rules, state policy, farm bill, cost share programs such as EQIP)
- Rainfall capture across landscapes
- Recycling, reuse

Rangeland, Grazinglands, and Cow-calf Operations

Lead: Animal science and rangeland ecology with ARS, NRCS
Issues/Topics:

- Sustainable rangelands = Sustainable operations = Sustainable environment
- Projections of climate change impact on grazinglands and ranch management
- Long-term research programs since it is a long-term system
- Holistic/systems approach (functional ecosystem) — wildlife and other
- Goal of optimum production, not maximum production (temporal economics)
- Risk management/marketing
- Vertically integrated systems to meet global markets
- Grazing strategies for range/soil health — managing soil carbon
- Livestock management and disease, genetics, etc.
- Employing prescribed burns in management
- Role of forages in an integrated system, more grass and less gas and capital
- Ecosystem services and fee-based uses (wildlife, hunting, etc.)
- Sustaining nutritional livestock needs (brush control, forage management, grazing)
- Adapted forages and hay operations
- Drought, flood, and wildfire response plan
- Animal welfare (pests and diseases – cattle fever tick)
- Programs to address land fragmentation across producers
- Application of easements
- Potential role of goats that eat brush plus heat tolerant
- Implications of land ownership (lease operations) on management
- International/export markets-policy implications
- Labor issues (immigration)
- Extend basics of production by extension — new delivery approaches
- Urban encroachment
- Greenhouse gas emissions
- Animals
    - Enhance protein production while improving resource stewardship

  - Efficiencies and production yields of moderate-framed cows and large-framed cows
  - Enhance the economic viability of beef production systems
  - Enhance the social responsibility and acceptability of beef production
  - Heat tolerance
- Need training in ranch management (professors to ranchers and vice-versa)
  - Link with successful producers
  - Focus on small producers (increasing number over time) — fragmentation
  - Use Mr. Emmons as an example of rebuilding the soil (on-ranch research)

Forestry

Lead: University forestry departments, state forestry agencies, USDA Forest Service
Issues/Topics:

- Ecosystem impacts of forest on water quality, carbon sequestration, soil health, and biodiversity
- Forest resiliency strategies toward mitigating climate change and associated stressors
- Species migration and site appropriateness
- Benefits of prescribed fire and wildfire prevention
- Fertilization and thinning to offset prolonged drought
- Natural regeneration to establish drought-tolerant crop species
- Urban forest resiliency strategies towards mitigating climate change and associate stressors
- Economic factors
  - Timber growth and inventory
  - Market uses and markets for wood — incentives for landowners to plant trees
  - Monetize traditional and non-traditional markets related to forests
- Federal and state regulations/policies impacting management
- Public perception/social acceptance — value of forest, ecosystem services, and wood fiber
- Updates and training of forest management decision support tools and silvicultural sciences to ultimately enhance multiple-objective impacts on the ground

Cropland (dryland and irrigated production)

Lead: State agricultural experiment and extension agencies, ARS, NRCS, commodity organizations, private sector (seed companies)
Issues/Topics:

- Climate/weather tools and projections
- Climate change projections and response of alternative crops
- Crop breeding for heat and drought tolerance and pest resistance
- CRISPR for gene editing for favorable attributes including health
- Crop rotations
- Cover crops
- Irrigation
- Efficient and supplemental irrigation
- Transition from irrigated to dryland over the Ogallala Aquifer
- Soil health and appropriate agricultural practices
- Integrate small grain with stockers
- Precision farming (data processing, early warning, decision support tools)
- Minimum till
- Rotations
- Risk management (insurance, diversification, including policy tools)
- Modernize extension outreach, apps for farmers

CAFOs (systems analysis to capture the interrelationships)

Lead: Colleges of veterinary sciences, agricultural experiment stations, engineers, industry
Issues/Topics:

- Animal health (impacts with climate change)
  - Disease emergence
  - Surveillance
  - Disease transmission
  - Vectors including wildlife as a vector of disease
  - Resistance to drugs
  - Resistance-alternative-adaptive management (i.e., AMR)
  - Pathogen control
  - Eradication of cattle fever tick
  - General concerns such as FMD, ticks, PRRS, etc.
  - Alternative therapeutics
  - Heat tolerance
  - Management to reduce stress
- Technology
  - Labor decreasing/robotics
  - Facility water recapture, management, reuse
  - Heat mitigation
  - Increased conversion efficiency
  - Hormones
  - Pre-harvest technologies for food safety and consumer acceptance
  - GMO feeds (studies of value compared to non-GMO feeds)
  - Impact of GMO feeds on livestock, meat and milk
  - Feed value under climate change
  - Odor and dust issues
  - Facility design
  - Waste management
- Communication
  - Speak with one voice across agriculture
  - Outreach to small and hobby producers
  - Interaction with producers, retailers, and policy makers
  - Using science to address regulations
  - Trade issues

Tourism, Recreation, and Ecosystem Services

Lead: Recreation and tourism sciences, Ducks Unlimited, Nature Conservancy, wildlife and fisheries
Issues/Topics:

- Palo Duro Canyon
- Hunting
  - Quail
  - Pheasant
  - Deer
  - Feral swine
  - Water fowl (ducks, geese, etc.)
- Bird watching (sandhill crane, ducks, woodpeckers, other)
- Fishing, boating, and camping (agriculture and forestry land uses affect surface water bodies)

- A day on the farm/ranch (visit a CAFO, harvesting crops, processing such as a gin)
- Roadside marketing (farmers markets)
- Ecosystem services from range to cropland to timberland to areas like Palo Duro

General Overlapping Needs

Climate Change and Adaptation

- Pests and diseases
- Unique by location, user, etc.
- Need for science and projections
- Weather forecasting priority for short run
- Mesonet system across the region

Communication

- Among scientists
- With producers
- With general public

Technology

- For all agricultural and forestry components
- Genetics
- Robotics
- Data processing and delivery for decision-making
- Unmanned aerial systems/sensors
- Not a cure all

Management

- Use of technology for advanced management
- Real-time decisions
- Data needs and application
- Temporal decision-making

Integrated Systems Approach

- Recognize the interrelationships and impacts
- Diversification
- Path of adaption for changing factors such as climate and declining Ogallala Aquifer

Behavior

- Social influences
- Perceptions
- Reluctance to make changes

Policy and Markets

- Impact of policy, farm bill, regulations, cost share programs, etc.
- Labor issues
- Markets and price of commodities
- Ecosystem services/value

Education and Training for Next Generation of Scientists

Appendix A

White Papers Developed for the Conference

The white papers are available at the conference website

http://twri.tamu.edu/el-reno

Titles and Authors are listed below

Climate Considerations
John Nielsen-Gammon, Gary McManus, Xiaomao Lin, and David Brown

Food and Fiber Production Systems
Travis D. Miller and Daniel L. Devlin

Range, Grassland, and Livestock Management
Justin Waggoner, Richard Teague, and Charles R. Long

Concentrated Animal Feeding Operations (CAFOs)
Joel DeRouchey, Brent Auvermann, and Chris Richards

Forestry
Eric Taylor and Larry Biles

Arthropod Pests and Plant Diseases
Phillip Mulder

Economic Drivers
John Tracy

Appendix B

Summary of the Breakout Group Discussions as Submitted

Dryland and Irrigated Crop Production

Irrigation application efficiency

- Efficiency of irrigation delivery systems (LESA, LEPA, drip, etc.)
- Impact of disease on WUE
- Improving dryland systems
- Limited irrigation and use of all the land
- Assess reducing current water use to ensure future availability

For all categories, improve:

Communications

- With producers
- With consumers
- Modernizing extension for effectiveness and determining what success in reaching people/increasing adoption looks like.
- Improving research and communication efficiencies through collaborative partnerships
- Talk across disciplines
- Understanding markets/economics and levers that can get pulled to increase options/flexibility for producers
- Engaging/recruiting/retaining young producers via technology
- Improving three-way relationship between new technology providers, academics/extension and producers

Agricultural infrastructure

- Warehouse
- Transportation
- Water infrastructure
- Aging infrastructure
- Grain handling
- Conservation structures
- Gins/processing facilities

Technology

- WUE
- Climate/weather tools
- Food safety and quality
- Partnerships

Crop adaptation related to climate shift

- Varieties-breeding
- Hybrids
- Genetics
- Varieties of adapted crops that have greater water use efficiency
- Crop improvement/crop diversity

Improving agronomic systems management to increase resilience to climate variability

- Terraces
- Soil health/cover crops applied appropriately by region
- Rotations

Integrated crop-livestock interface

- Future = reinventing the wheel: crop rotation, diversity, small grain grazing
- Alternative crops
- Invasive pests and disease management (i.e., sugar cane aphid)
- Risk management at the practical field level/management level but which also includes crop insurance, commodity programs, hybridization

Subcategories: communication and dissemination of this information

- Educate producers on the improvements they can get.
- What to do with land that doesn't get irrigated. Graze it? Add wind turbines?
- Think about improvements that can be made, for example rotating cotton with sorghum or wheat to combat nematodes.

Weather and (vs) climate data and its utility for producers/other agriculture stakeholders/planners/tool developers; climate/weather tools for decision-making.

- What information do producers need; how localized does it need to be?
  - Producers need to know how rapid the change will be and need it brought down to a regional level.
  - Farmers are more interested in season-to-season, but the breeders and the people trying to make future tools for the producers to use are the climate scientists' best clientele. Farmers are interested in the weather; they are less interested in climate.
  - Need the data/information in a palatable form.
- What is the storm size that we need to be adapting to?
- What's practical, so that we don't rip out infrastructure that's been put in from a conservation standpoint? Climate information that we can all use.
- We need contextualized information for different users, cotton producers versus wheat for example.
- Producers need data on many different levels; they need to know exactly what is happening with the wind on their farm because it can be very expensive if they miss or if the wind shifts while applying pesticides.
- Short- and long-term data; NASS data is used for many things including inappropriate uses.
- More cross communication between climate scientists and agriculture stakeholders.
- How climate models can be used: Soil moisture + projected climate = fairly reliable yield estimates and helps producers make production and marketing decisions.
- ET and irrigation scheduling tools.
- Improving Mesonets in different states: funding was for agriculture but also useful to predict flooding/protect infrastructure; increased installation of weather stations for multi-use situations for the value this provides in terms of limiting risk to urban and rural folks alike.
- Integrating ideas/consolidating comments into categories.

Connecting the dots between climate trends and agronomic capacity

- If nighttime temperatures increase significantly, do we really know what crops won't grow? Can we make the global climate models more localized/scaled down to high resolution at the state or county level? With climate change, which is going to do you the most damage — hot temperatures later on when you are trying to get grain fill, or a hail storm? Shortening the grain fill window during production has been the approach to date. The odds of getting a late freeze are less than having hot temperatures.

Communication and dissemination

- New apps and other ways to help people find and use this data

Food safety and quality

- Understanding climate change impacts on disease/mycotoxins (and related bio-controls that can be used as tools) peanuts/corn and impacts on food safety and quality

Economics/markets

- Policies
- Crop insurance
- Farm bill
- Prices
- Understanding diversity even across the Southern High Plains and contextualizing what can/should be done given rainfall/irrigation situation at the sub-regional level and prices
- Informing/improving risk management (planting date, crop selection, etc.)
- Communication/dissemination: provide information/education to legislators

Grazinglands-Livestock

Discussion

- Too much of what's been taught is how to do more with more; need to focus more on how to get more from less; looking at diminishing resources (labor, capital, resources).
- How can we look at things more holistically?
- Issues of adaptability of research; what might work in one area/soil may not work in others.
- Funding drives research with short-term expectations while we need longer-term research.
- Issues with societal impressions of what we do and societal pressures

Issues

- Manage as a whole ranch system, an integrated systems approach (ranch business system)
  - wildlife
  - livestock
  - other uses
  - indicators
  - benchmarks ($, production)
- Regional multi-disciplinary projects
- Research to connect biology, production/economic, and social aspect
- More with less; aim for optimum production instead of maximum production
- Optimize inputs
- Complimentary forages and systems to native grass
- Management of plant community; native plant communities = resilient plant communities
- Need to study social elements to get engaged and influence the next generation
- Extension typically focusses historically on inputs and strategies; need to get back to basics of animal production — a base change from where extension is now.
- Dealing with leased land (extract as much as possible in near terms); bring improvements into lease agreement; dollar value of improved management within lease arrangements
- Maintain fire as a management tool
- Environmental specificity (what works everywhere and what does not)
- Building adaptive capacity and skills in farming/ranching community. Giving them tools and empowering them
- Successful adaptation strategies
- Successful approaches to dealing with extremes
- System flexibility – assess variability, monitor indicators
- Ranch health indicators – promote BMPs
- Critical role of managing soil carbon
- Need new funding model that supports long-term research but can't wait on this and need to learn from existing ranchers (integrate the good managers strategies into research network)
- Work with consultants
- Define effect of management and/or managers on desired goals

- What variables should be monitored/measured, trigger points, etc. (effective planning – being proactive vs. reactive)? Soil organic matter, infiltration rate
- Policy research to prevent unintended consequences (i.e. support ineffective producers by bailing out failing operations during drought; do not subsidize???)
- Keep message simple for marginal ranchers
- How do we "get the science behind what effective ranchers are doing" to disseminate to surrounding producers? How do we fill that gap? New delivery approaches needed.
- Science and application must agree to promote and reach more people and overcome "ranch heritage."
- Establish consortium to put together the right pieces of the model. New approach should integrate researchers, extension educators, private industries, and ranchers. Focus on better interaction between ranchers and research/extension.
- Identify what practices should be eliminated/avoided and what practices should be advanced.
- Strategic producer relations – establish peer groups (of producers and researchers) to assist other producers; producers value other producers' knowledge/opinion
- Young Rancher academy/training opportunity
- Need survey of what top ranchers are doing
- Need better communication of active research
- Must have good science to back management of good ranchers to change traditional practices; do on-ranch research instead of plot research to evaluate what happens on large-scale.
- Better college-level training on ranch management; not training people with needed skills
- Need
  - Instructors at university
  - Practical management courses
  - Management framework to follow prototype
- Formal mechanism for better integration of good practitioners and research; involvement of Climate Hubs, universities, USDA
- More rancher input needed into university research; What research questions do good managers have?
- Modify extension model (do more with less); for example, make movies/videos, etc. to reach audience
- Need key BMPs (blueprint) based on goals, i.e. stocker operation vs. diverse operation for wildlife, cattle, etc.
- Focus needed on small producers (27,000 new landowners in Texas since 1997 with most managing less than 100 acres)
- Identify key drivers to success and common themes among successful ranches (identify traits of successful ranches)
- Understand connection between vegetation management and soil health and ranch profits (and understand these from a regional perspective)
- Understand unintended consequences of management practices
- Functional ecosystem requires infiltration and storage, which requires vegetation management
- Must do a better job of management in the face of climate variability
- Incorporate stockers, etc.?
- Need drought and flood plan
- Partnerships to disseminate information
- Assess successful ranches to identify what is going on from systems perspective (water, soil, animal, vegetation)
- Feedlot cattle death has doubled, and medicine costs tripled; Genetics have something to do with this.

Overall themes/objectives

- Need for science-based research and outreach and restoration of research/extension
  - Improve production research
  - Improve implementation of what we know
- Increase synergy between research, extension and producers

Key research questions

- **In view of changing climate, what makes a successful/sustainable ranch in terms of the following and why is it working?**
  - Sustaining nutritional needs of livestock/wildlife
    - Brush control
    - Forage management
    - Grazing management
  - Water management
    - Availability of water for livestock and water for forage (i.e. soil water/soil health)
  - Livestock/wildlife management
  - Soil health
  - Drought response (i.e. what worked best in 2011)
  - How to make ranch-level assessments?
  - How to prioritize ranch-level implementation?
  - Marketing opportunities
  - Economics
- **Where will we get researchers of the future (need to focus on ranch management)?**

Tasks

- Create research advisory board made up of ranchers and focused on climate theme
- Create industry consortium
- Identify funding support groups/organizations (some funders and some supporters)
- Review CEAP findings and published literature
- Use interdisciplinary research to perform case studies on successful/sustainable ranches (in terms of the topics listed above) to evaluate whole ranch management system
- Compare top 10% of producers to bottom 10% producers
- Evaluate in terms of climate variability
- Deliver findings to the ranching community (convince by showing the profitability of these practices)

Partners

- Suitable/successful ranches
- Consultants/educators
- Consumers
- Wildlife groups
- State/federal agencies
- Industry
- SWCDs, NRCS FOs

Funding sources

- Industry
- Climate Hubs
- LTAR – funds go primarily to the particular sites, but there is a lot of opportunity for leveraging these with other funding sources and university partners; For example, graduate student research within context of LTAR, small funding agreements, etc.
- USDA-NIFA (Sustainable ranching)
- NSF Integrated Human-Environment Program
- Commodity groups (matching for federal grants from NCBA, Farm Bureau, TSCRA, TCFA, GLCI)
- NRCS NHQ (CIG grants)
- Professional societies (SRM, ASA, etc.) as partners in communication and outreach

Timeline

- Need long-term research
- Produce 10-year plan
- Complete report (next 3 mos.)
- Create advisory board or utilize existing boards to identify successful ranches, ranchers, and management practices (next year)
- Conduct potential survey of successful ranches regarding practices (next year)
- Assess existing publications (next year)
- Develop/submit USDA-NIFA (and other) proposals to support case studies (next year)
- Perform case studies, which will require 6-8 years, to gather the needed information

CAFOs

Social

- Sustainability awareness of animal health
- Consumer perception and marketing
- Odor and dust
- Speak with one voice across agriculture
- Education of the public
- Land grant image of bias in support of ag
- Outreach of small and hobby farmers

Crops

- Value of milk as a fertilizer if farm programs require reducing supply
- Impact of GMO crops fed to livestock, meat and milk
- Update traditional vs GMO studies
- Crop advances to maintain animal value
- Switch from irrigated silage to dryland forage/hay

Animals

- Liver abscess treatment
- Alternative therapeutics
- Technology efficiency – maintain current and advance
- Pre-harvest food safety
- Preconditioning of animals before feedlot
- Extremes in temperature impact proper care for animals

Pests/diseases

- AMR
- Invasive pests and diseases
- Mild winters threaten things such as ticks
- Process to eliminate the cattle fever tick
- FMD (Foot and Mouth Disease) generally and plans if enters the U.S.
- PRRS (Porcine Reproductive and Respiratory Syndrome) – breathing reproductive issue
- Wildlife vector diseases
- Captive wildlife production-use of drugs

Policy

- Research and communication with producer
- Research and communication with retailers
- Research and communication with policy makers
- Impact of final retailer constraints on methods of production
- Trade – constraints from importing country
- Use science to address regulations
- Extreme heat and desire to move animals but have transportation issues
- Regulations impact fuel that can be used

Facilities and transportation

- Waste water effluent, least cost, effective
- Water conservation, effectiveness
- Value-added effluent – nutrients and such
- Pre-harvest food safety
- Efficiency of operations
- Robotics and technology – labor issue-automation
- Improved design of facilities
- Automatic feeder vs manual
- Cross-ventilated barns for dairy
- Segment to maximize market potential
- Implications of low emissions policies in vehicles such as no diesel
- Changes in fuels (natural gas) to address greenhouse gases
- Conduct systems analysis to capture the relationships
- Identify unintended consequences of alternative

Research priority

Technology

- Labor decreasing technologies and facilities
- Facility water recapture, management, and re-use (other)
- Heat mitigation strategies/technologies

Feed value of feed stuff as they adapt to changing climate (other)

- Increased conversion efficiency (immediate)

Animal health

- Disease emergence
- Surveillance
- Disease transmission
- Vectors/carriers
- Prevalence and severity of diseases with climate change
- Resistance – alternatives-adaptive management (i.e. AMR)

Pre-harvest technologies for food safety and consumer acceptability

- GMO feeds
- Pathogen control
- Hormones
- Animal health

Forestry – Silviculture

Issues

- Non-native invasive species
- Market for traditional (lumber) and non-traditional forest products – driver of proper management
- Impact of native pests on forested systems
- Valuing forests for their ecosystem services including water quantity/quality; carbon sequestration, soil health, air filtration, biodiversity
- Timber growth and inventories
- Species migration
- Resiliency to environmental stressors and change in risk for catastrophic loss
- Wildfire potential/duration of season
- Silvicultural tools available for management may change; will current tools (e.g. tree planting windows, Rx fire, herbicides, etc.) still be effective?
- Current and future carrying capacity of land
- Land use change, parcelization, and fragmentation
- Social acceptability, landowner engagement, and public perception impacting ability to manage forests properly
- Global change
- Federal and state regulations/policy impacting management of forests and trees
- Multi-crops/agroforestry systems
- Forest certification/accountability

Needs

- Silvicultural science
- Improved policy guidelines
- Incentives to landowners for proper management
- High quality marketing/education resources
- Performance measures

Opportunities

- Silvicultural treatments
  - Proper use of fertilization and thinning to offset changes due to prolonged drought conditions to increase resiliency
  - Using natural regeneration as a tool to establish more drought-tolerant crop species while minimizing economic inputs for establishment

Issues

- Silvicultural treatments – ability to conduct treatments with changing windows of opportunities due to weather pattern changes, growing season changes, and drought conditions
- Resiliency to environmental stressors and resulting carrying capacity
- Ecosystem services to include water quality/quantity and soil health
- Impact of native and non-native pests
- Species migration/biodiversity/woody encroachment/land use change
- Public perception/social acceptance/landowner engagement
- Local, regional and global markets for wood fiber and products

Overarching Opportunity

Continue to expand and embrace the use of new and developing technologies while encouraging younger generations to follow careers in forestry and natural resource management.

- Silvicultural treatments – ability to conduct treatments with changing windows of opportunities due to weather pattern changes, growing season changes, drought conditions
  - Proper use of fertilization and thinning to offset changes due to prolonged drought conditions to increase resiliency
  - Using natural regeneration as a tool to establish more drought-tolerant crop species while minimizing economic inputs for establishment
- Resiliency to environmental stressors and resulting carrying capacity
- Ecosystem services to include water quality/quantity and soil health
  - Promote active and purposeful forest management for unengaged landowners
- Impact of native and non-native pests
- Species migration/biodiversity/woody encroachment/land use change
  - Assist migration
- Public perception/social acceptance/landowner engagement
  - Educate public and policy makers (local/state/federal) on value of forest, ecosystem services. and wood fiber
- Local, regional and global markets for wood fiber and products
  - Aggregate small tracts of land to meet/lessen the economy of scale for accomplishing

Overarching Need

Recruit, retain, and train younger generations into the forestry and natural resource management profession.

- Silvicultural treatments – ability to conduct treatments with changing windows of opportunities due to weather pattern changes, growing season changes, drought conditions
- Resiliency to environmental stressors and resulting carrying capacity
- Ecosystem services to include water quality/quantity and soil health
  - Monetize traditional and non-traditional markets including ecosystem services (e.g. carbon, water, cultural, etc.)
  - Peer-to-peer mentoring and effective ways of communication
- Impact of native and non-native pests
- Species migration/biodiversity/woody encroachment/land use change
  - Understand niche requirements as related to desired future requirements
- Public perception/social acceptance/landowner engagement
  - Research on identifying trees and genotypes with greatest longevity, drought, and pollution resistance
  - Research/develop effective ways to communicate with public
- Local, regional and global markets for wood fiber and products
  - Need to expand and/or develop new markets both locally and globally, which directly influences forest management

Appendix C

Participants

Beef Producer
Jim McAdams

Colorado State University
Amy Kremen
Meagan Schipanki

Congressman Lucas' Office
Bennett Beard

Kansas/Creekridge Farm/Kansas Forestry Association/ Kansas Rural Center
Wayne A. White

Kansas Corn Growers Association
Dale Fjell

Kansas State University
Joel DeRouchey
Daniel Devlin
Walter Fick
Bill Golden
Audrey King
Xiamomao Lin
Peter Tomlinson
Justin Waggoner

Kansas State University – Kansas Forest Service
Larry Biles

Lugert-Altus Irrigation District
Tom Buchanan

OACD and Farmer-Rancher
Jimmy Emmons

Oklahoma Forestry Services
Scott Huff

Oklahoma Oilseed Commission
Ron Sholar

Oklahoma Pecan Growers Association/Flying G Ranch
Mike Spradling

Oklahoma Pork Council
Roy Lee Lindsey

Oklahoma Sorghum Association
Jordan Shearer

Oklahoma State University
Phillip Alderman
Omkar Joshi
Phil Mulder
Ryan Reuter
Chris Richards
Saleh Taghvaeian
Justin Talley
Jason Warren
Rodney Will

Oklahoma Wheat Commission
Mike Schulte

Plains Cotton Growers, Inc.
Shawn Wade

Redlands Community College
Reonna Slagell Gossen

South Central Climate Science Center
Jessica Blackland
Mike Langston

Southern Climate Impacts Planning
Margret Boone
Rachel Riley

State Conservation Commission
Rod Vorhees

Texas A&M AgriLife
Ron Lacewell
Bob Whitson

Texas A&M AgriLife Extension Service
Brent Batchelor
Brian Hays
Travis Miller
Eric Taylor

Texas A&M AgriLife Research
Katie Lewis
Charles Long
Monte Rouquette
Charlie Rush
David Briske
Julie Howe

Texas A&M AgriLife Research – Texas Water Resources, Institute (TWRI)
John C. Tracy
Kevin Wagner (now Director of Oklahoma Water Resources Center)

Texas A&M Forest Service
Shane Harrington
Eric Taylor

Texas A&M University
John Nielsen-Gammon

Texas A&M Veterinary Medical Diagnostic Laboratory
Jessie Monday

Texas Association of Dairymen
Darren Curtis Turley

Texas Cattle Feeders Association
Josh Winegarner

Texas Corn Producers Board
Scott Averhoff

Texas Forestry Association
Ronald Hufford

The Noble Foundation
Hugh Aljoe

USDA Agricultural Research Service
David Brown, Southern Plains Climate Hub
David Brauer, Bushland
Prasanna Gowda, Southern Plains Climate Hub
James P.S. Neel, Southern Plains Climate Hub
Cait Rottler, Southern Plains Climate Hub
Jean Steiner, Southern Plains Climate Hub
Ken Turner, Southern Plains Climate Hub

USDA Forest Service – Rocky Mountain Research Station
Paulette Ford

USDA Natural Resources Conservation Service
Mike Oliver

Many thanks to Redland Community College staff for their assistance
and allowing us to use their facilities.

REDLANDS
COMMUNITY COLLEGE