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

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

Agenda

July 18

8:30	Welcome, General Comments, and Overview	Ron Lacewell, David Brown
8:45	Climate Outlook and Implications for the Region	John Nielsen-Gammon
9:15	Irrigated and Dryland Food and Fiber Production	Travis Miller
9:45	Range, Grassland, and Livestock Management	Justin Waggoner
10:15	Break	
10:30	CAFOs	Joel DeRouchey
11:00	Forestry and Silviculture Management	Larry Biles
11:30	Pests and Diseases	Phil Mulder
12:00	Regional Economic Drivers and Future Opportunities	John Tracy
12:30	Lunch	

1:30 **Breakout Groups for discussion and identification of priority opportunities for next 10 years**
Each group is to consider implication of expected changes in climate and needs in policy, implications of pests and diseases as well as wildlife and agro-tourism opportunities.

Use the "Open/Narrow/Close" approach.

- Brainstorm: each person provided opportunity to identify1-2 research/extension needs
- Combine those topics that are similar
- Prioritize

Breakout Groups

Irrigated and Dryland Food and Fiber Production	Devlin/Miller
Range, Grasslands, and Livestock Management	Waggoner/Teague/Long
CAFOs (feedlots, dairy, swine, etc.)	DeRouchey/Richards
Forestry and Silviculture	Taylor/Biles

5:00	Adjourn	
6:00	Catered Chuck Wagon Dinner at Darlington Chapel	Jimmy Emmons, Oklahoma Farmer

Agenda cont.

July 19 – University and Agency resource participants (stakeholders welcome)

8:30 **General reporting/presentations from the previous day**

Irrigated and Dryland Food and Fiber Production	Devlin/Miller
Range, Grasslands, and Livestock Management	Waggoner/Teague/Long
CAFOs (feedlots, dairy, swine, etc.)	DeRouchey/Richards
Forestry and Silviculture	Taylor/Biles

Comments on Cross Cutting Topics

Climate Outlook	Nielsen-Gammon
Pests and Diseases	Mulder
Economic Future Opportunities	Tracy

10:00 Break

10:15 **Breakout working groups by task: Outline 10-year research/extension plan**

Leads same as above with resource folks involved and the goal to identify key research questions, tasks, partners, funding sources with a timeline incorporating climate factors, pests and diseases, economic future opportunities, wildlife, and agro-tourism.

Irrigated and Dryland Food and Fiber Production	Devlin/Miller
Range, Grasslands, and Livestock Management	Waggoner/Teague/Long
CAFOs	DeRouchey/Richards
Forestry and Silviculture	Taylor/Biles

12:00 Adjourn

1:00 Core working group finalize plans for next steps of report

Climate Considerations

John Nielsen-Gammon[1], Gary McManus[2], Xiaomao Lin[3], David Brown[4]

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Introduction

The climate of the Southern Plains has been monitored with weather instruments since the mid-19th century. The data reveal a region subject to dramatic swings in climate conditions. The history of agriculture in the region tells a similar story, with years of plentiful rains alternating with severe droughts, such as the 1930s Dust Bowl. Computer simulations of the atmosphere help scientists confirm many relationships found in the historical data, such as the tendency for wet winters in the Southern Plains during El Niño and dry winters during La Niña, especially farther south. Computer simulations also show that many of the observed longer-term changes in Southern Plains climate are consequences of a global-scale warming that will continue for many decades to come.

Identifying which specific climatic changes will continue or emerge in the future requires careful comparison of observations and computer simulations. The task is made harder by limited historical observations of extreme weather and by the broad-brush nature of climate models. The relevant aspects of local weather must be inferred from large-scale projections of future climate change via a process known as downscaling. Inaccuracies in computer models, projections, and the downscaling process all mean that the future long-term changes to Southern Plains climate are only known in general terms; consequently, Southern Plains agriculture must be resilient to a variety of possible outcomes.

Current Knowledge

Observed Changes

Both temperature and precipitation have increased across the Southern Plains since the beginning of the 20th century. Temperature increases so far have averaged about 1.5°F over the 20th century, and precipitation has increased by as much as 5%, albeit with large variations from year-to-year and decade-to-decade. Heavy rainfall events have increased in frequency and magnitude. Historical data for tornadoes and hail are not reliable enough to be used to determine whether a trend is present in these types of severe weather.

Variations in drought conditions from year-to-year and decade-to-decade are triggered by changes in sea surface temperature patterns in the Pacific and Atlantic oceans. The Dust Bowl drought is thought to have been exacerbated by poor land use practices, while precipitation may have been enhanced in recent decades by growth in irrigated agriculture and surface water.

Projected Changes

It is clear that temperatures will continue rising over the long term, as carbon dioxide and other greenhouse gases continue to become more plentiful in the atmosphere. By the middle of the 21st century, typical temperatures in the Southern Plains are likely to be 4°F to 6°F warmer than the 20th century average, making for milder winters (with less snow and freezing rain), longer growing seasons, and hotter summers. Rainfall trends are much less certain. The majority of climate models favor a long-term decrease, but most projected changes are small compared to natural variability. Extreme rainfall is expected to continue to become more intense and frequent.

The most important natural hazard for agricultural and forestry operations is drought. Though rainfall changes are likely to be small, Southern Plains drought is expected to become more severe due to several other factors. First, more extreme rainfall means that rainfall will come in more concentrated periods, leading to relatively more runoff and relatively less infiltration into the soil. Second, higher temperatures mean that evaporation rates are likely to increase from soil, surface water, and plants. Carbon dioxide increases will help plants retain water but not enough to overcome the higher temperatures in most circumstances. Computer simulations of the consequences of all these changes on soil moisture in the High

Plains indicate progressively greater depletion, such that what today is considered a moderate drought will become the new normal in a few decades.

Key Knowledge Gaps

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. 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. Projections of these important details of climate change, as well as its overall magnitude, are likely to continue to improve as observational evidence increases and computer technology improves.

Another area of active research is the conversion of climate change information into comprehensive sector-specific recommendations. Changes in yield and climate suitability depend on the characteristics of the particular plant and breeds, though yield variability is generally expected to continue to increase. Without adaptation, climate change is expected to negatively impact wheat and maize production in most locations, while soybean production may improve in many areas. The costs and benefits of changing crop types and management practices depend on changes taking place in other production regions across the country and around the globe. It is also important to know how competing producers will respond to climate change, whether it be proactive planning, gradual adjustment, or an abrupt response to catastrophic weather and climate events.

Food and Fiber Production Systems

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[2]Director, Kansas Center for Agricultural Resources and the Environment, Kansas State University, Manhattan, KS

Introduction

The Southern Plains of the U.S. is a vast and highly productive agricultural region that contributes greatly to the overall national agricultural food and fiber security. National Agricultural Statistics Service (NASS) statistics from 2016 show that farmers in Texas, Kansas, and Oklahoma planted 17.3% of all U.S. acreage of field and fiber crops, including grain sorghum–81%, cotton–60%, wheat–37%, hay–20%, corn–9% and soybean–6%. In all of the crops produced in the Southern Plains, farmers have adopted and continue to modify risk-adverse cropping systems, as crop damage and loss are frequently associated with drought, heat, freeze injury, delayed planting, and other crop failures due to weather events. Additionally, there is an expected shift in economically important crop pests in response to climate change. Increased variability and change in climate pose new risks in crop production, and new solutions need to be developed to minimize these risks including mitigation strategies for adverse events (such as catch crops). Current production systems have evolved from decades of successful research and Extension programs, and continued input from agricultural research and extension will be vital in minimizing risk due to climate variability and change.

Current Knowledge

Genetic Adaptation and Resilience

Scientists and educators have made remarkable advances in crop genetics in the last 75 years, with most of this advancement addressing the reduction of production risk through improved stress tolerance. The introgression of new genetics to provide climate resilience to our crops and forages will perhaps be the most important tool to help producers adapt to increasing climate risk. Specifically, this process addresses crop tolerance to heat and drought as well as stresses imposed by insects and diseases. It involves a broad array of technologies and processes such as traditional plant breeding, development of molecular markers, identification of genes and sources of genes for climate resilience, multi-environment crop testing of new genetics, gene editing, genetic transformation and mutagenesis. These all serve as tools for the rapid advancement of genetics to minimize climate risk to agriculture producers. Meeting the pressing need of crop genetic improvement requires a large, integrated team including basic bench scientists working at the molecular level, plant breeders, agronomists, entomologists, plant pathologists and extension specialists in the field that manage uniform variety trials and educate producers on advances in crop production. While new molecular tools have accelerated crop development, making significant progress in climate resilience is a lengthy and costly process.

Water Resources

Water deficits are the most limiting variable in crop and forage production in the Southern Plains, in both irrigated and dryland systems. Potential evapotranspiration often exceeds the ability to deliver water due to wells with diminished pumping capacity. Declining aquifers and increasing competition for water resources from urban and industrial water users are reducing the amount of water available for irrigation. Persistent high evaporative demand associated with elevated temperatures, low humidity and high wind speed increase water demand and challenge both dryland and irrigated producers. Pest management is vital to enhance water-use efficiency, as crops competing with weeds, or crops injured by diseases or insects are less water efficient. For example, producers often continue irrigation long past the point of any possible return on crops with significant injury from plant disease or nematodes. Conversely, crops with moisture stress are more susceptible to damage from aphids and other insects. Mitigating water issues will require a multipronged approach: more efficient irrigation, which involves more efficient water delivery and reduced evaporative losses; matching irrigation capacity to crop requirements, utilization of advanced techniques to assess crop stress and irrigation timing, plans for rapid response to biotic and abiotic stress, site specific irrigation technologies, an integrated crop management program, identifying alternative crops and cropping patterns to address declining water supplies and matching available irrigation to the optimum crop growth stages.

Alternate Cropping Systems

Tillage systems provide another risk management tool. They preserve crop residue to reduce erosion, lower canopy temperatures, decrease evaporative water loss, allow for deep and extensive root systems, and enhance the infiltration of precipitation or irrigation. High residue tillage systems are only effective if there is sufficient crop residue to protect the soil, preserve moisture and increase water infiltration.

Alternative crops can fit in a sustainable production system that adds to surface residue and improve soil quality. We currently see millions of acres in either monoculture cotton or wheat. We need to take a serious look at alternative crops in our production systems to reduce risk and improve soil quality. There is an influx of wine grapes in the Southern Plains in cropping systems previously dedicated exclusively to cotton. Are there other high-value crops that can bring more income while reducing the overall footprint of irrigated acres?

Economically viable systems for crops with low residues, e.g. cotton, need more work: how can more high-residue crops be incorporated while maintaining farm income typically associated with cotton? Ongoing research on cover crops to enhance surface residue has had variable success in the lower precipitation areas of the Southern Plains, requiring the application of irrigation water to achieve stands and to increase biomass. How and where can cover crops be successfully incorporated in to Southern Plains production systems? Which crops, if any, can fill that role? What role do livestock play in traditional cropping systems of the Southern Plains?

It is time for a serious look at cropping systems and crop/livestock systems that reduce overall risk of production and enhance both the resilience of the crops and cropping systems as we face ever higher demands for food, feed, fiber, and fuel. This suggests reaching the next level in precision agriculture related to fertilization, pest management, irrigation, cropping patterns and such while being environmentally beneficial. It remains to be seen what role unmanned aerial systems (UASs) will play. but certainly the application of UASs, manned aircraft, and satellite information will be critical for management in the future.

Key Knowledge Gaps

- 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, field testing of advanced lines)
- Capacity to detect and to mitigate invasive pests (IPM capacity, improvement of pest management technology including insects, disease, mycotoxins and weeds)
- 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

Justin Waggoner[1], Richard Teague[2], Charles R. Long[3]

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Introduction

Range and grasslands are one of the dominant ecological features of the agricultural landscape in the Southern Plains and are particularly important to the region's beef industry. Forage resources are the foundation that the beef industry is built upon and provide a substantial amount of the nutrients cattle consume over their lifespan. Sales of cattle and calves provide 55.0% ($10.2B), 47.7% ($3.4B) and 51.3% ($13.0B) of annual agricultural income of Kansas, Oklahoma, and Texas, respectively, and 34.8% ($26.6B) of the nation's agricultural income (USDA 2012).

Natural resources such as range and grasslands must be used in ways that prevent depletion of those resources and that promote the ecosystem's sustainability for increased resilience of the range livestock industry. Modern forage-based beef production systems and individual operations must be sustainable — economically, environmentally, socially, and ethically — to survive over the long term. Also, production systems and operations should be resilient to challenges of climate, weather patterns, societal needs, market fluctuations, and other environmental pressures (Sawyer, 2015). Forage-based beef production research and extension need to be placed within the context of sustainability and these aforementioned challenges.

Key Knowledge Gaps

There are a number of different components in the system, thus multiple research opportunities exist in the following topic areas:

- Soil health (water filtration, nutrient cycling, carbon sequestration)
- Alternative grazing/management strategies (adaptive multi-paddock grazing)
- 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
- Environmental impacts of beef production and grazing systems
- 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
- Forage system adaptability given long-term climatic changes

Information and technology developed and disseminated from competent research and extension programs have historically impacted favorably 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.

Citation information is available from authors.

Concentrated Animal Feeding Operations (CAFOs)

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Introduction

Concentrated animal feeding operations (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.

CAFOs are defined as "lots or facilities (other than an aquatic animal production facility) where the following conditions are met: (i) Animals (other than aquatic animals) have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and (ii) crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility." The CAFO designation itself is independent of animal numbers and of animal liveweight. For regulatory purposes, a "large" CAFO is any such operation housing a species-specific, minimum number of animals of a species-specific, minimum average liveweight[1]. However, any livestock or poultry operation that discharges manure or wastewater into a natural or man-made ditch, stream, or other waterway may be designated as a "medium" CAFO at the discretion of the administrator of the U.S. Environmental Protection Agency. A determination of CAFO status has regulatory and permitting implications under the National Pollutant Discharge Elimination System (NPDES).

Current Knowledge

Due to the complexity of resource needs, such as employees, feed, feed preparation, water, housing facilities, and land availability for manure management, long-term stability within these businesses is critical. In the past several decades, CAFOs have faced public and regulatory pressure from an environmental standpoint relating to proper manure management, greenhouse gas and odor emissions, and overall animal density at a single location. Once a CAFO is established, the consistency of long-term water and feed resources is crucial, and changes in weather patterns in the Southern Plains could jeopardize the availability of those resources. Changes in irrigation allowances, individual water rights (quantity), and lower runoff to replenish surface water could have impacts on these basic needs of livestock operations.

Key Knowledge Gaps

To improve the long-term sustainability of CAFO operations, further development of on-site practices must be evaluated and disseminated to both producers and regulators. This may involve summaries of existing literature, conducting new research, developing economic modeling/analysis of existing or new practices, or engaging the private sector for business development. When considering the livestock industry in the Southern Plains, areas to consider may include, but are not limited, to:

- 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

[1] A bovine animal unit is defined as an animal equivalent of 1,000 lb liveweight. In practice, the 1,000-AU threshold equates to e.g. 1,000 head of beef cattle, 700 dairy cows, 2,500 swine weighing more than 55 lb, 125,000 broiler chickens, or 30,000 laying hens or pullets. See 30 CFR 122.23.

- manure and wastewater on limited-irrigation or rain-fed cropping systems.
- 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 – Impact on growth performance; efficiency of gain; impact on well-being and comfort; unintended or perverse consequences of shade mandates in climatic regions conducive to overnight thermal recovery (i.e., restoration of thermoneutrality).
- Evaporative cooling and dust control – Improved sprinklers or mister usage; 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.
- Animal health – Exposure to the feeding infrastructure as well as issues related to additives in feed and antimicrobial resistance.

Forestry

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Introduction

The diversity of forest types within the Southern Plains is broad. Forests are typically considered either rural or urban. An urban forest, a collection of trees that grow within a city or town, may not provide significant value in wood fiber, but they do provide numerous ecosystem services. The diversity of urban forests is great, and climate variability can bring a broad range of challenges to effective management. Rural forests are typically characterized as either timberlands or woodlands. Timberlands are forests grown to produce a wood fiber crop as a primary objective. Woodlands can provide some wood fiber but are typically either unmanaged or managed for objectives other than fiber production. Due to the complexity of forest landscapes within the region, climate change impacts on timberlands is the primary focus of this paper because these forests provide critical economic and ecological services to U.S. citizens.

As climate changes, soil moisture, nitrogen, and carbon cycles shift, impacting the productivity and sustainability of the forest resources in the Southern Plains. Addressing the immediate impact on productivity and sustainability of forest ecosystems due to changing climate variability is of immediate concern. For instance, hot/dry cycles may be hotter and dryer than previous cycles, affecting the ultimate carrying capacity of forested lands. Further, the Southern Plains region may also experience more frequent flash floods, perturbing bottomland regeneration and productivity.

Current Knowledge

One notable effort with far-reaching influence is the PINEMAP (Pine Integrated Network: Education, Mitigation, and Adaptation) project funded by the USDA National Institute of Food and Agriculture (NIFA). PINEMAP focuses on the 20 million acres of planted pine forests in the South and represents a strong umbrella for future activities. PINEMAP integrates research, extension, and education efforts of 11 southeastern land grant universities and the USDA Forest Service to enable southern pine landowners to:

- Increase carbon sequestration by 15% through silviculture and genetics,
- Increase efficiency of nitrogen and other fertilizer by 10%, and
- Increase forest resilience and sustainability under variable climates in the next few decades.

PINEMAP established a three-tiered monitoring network to develop carbon, water, and nutrient storage and flux baselines and responses to climate and management. Further, to optimize matching of seed sources to environment, PINEMAP used five pine seed source studies, established by the three southern tree improvement cooperatives, to refine seed movement guidelines within their respective breeding programs. PINEMAP also used genotyping technology to help more rapidly develop pine seedlings that are adapted and resilient to climate variability, better mitigate economic risks, and increase carbon sequestration.

PINEMAP's integrated modeling will provide predictions of how managed pine systems may respond over the next century in response to environmental change. Preliminary PINEMAP modeling results suggest that altered future temperatures and precipitation have a small negative impact on average provision of ecosystem services. However, thinning and lower planting density significantly improve timber production, carbon sequestration, and species richness.

PINEMAP's Decision Support System (DSS) provides regional information on the range and likelihood of future climate conditions and their impact on forest productivity. The DSS is a collection of web-based tools and educational materials to assist foresters with land management practice decision making, including tools to assess potential changes in risk factors such as pests, disease, and climate. These web-based tools transform output data from PINEMAP research into a framework which allows professionals and clients to make informed land management decisions.

Finally, PINEMAP is analyzing the life-cycle carbon balance of regional forest management systems and conducting multi-scale analyses of market and non-market forest benefits and services to provide the framework necessary to guide land manager decision-making under future management and climatic conditions.

Hardwood resources in the Southern Plains tend to fall more into the woodland category rather than timberland category. However, a few species are regarded as high value species throughout the region, hardwood pulpwood demand is high and constant in the southern portion of this range, and sawtimber markets exist requiring quality hardwood logs. For these reasons, research and outreach activities are ongoing in the Southern Plains region — albeit to a lesser extent — to examine climate change and market change impact on hardwood silviculture.

Research groups, companies, and cooperatives have conducted numerous pine and hardwood studies in the region, examining:

- Survival and growth performance of container seedling stock versus bare-root seedling stock under increased environmental stressors.
- Container design for improved root development, especially longleaf pine and oak.
- Adjustments to planting season/timing by planting stock to improve site acclimation for summer drought hardiness.
- Physiological differences of various loblolly pine, ash, and oak genotypes to understand differences in daily and seasonal water-use efficiency in response to vegetation control treatments.
- Herbicide timing on hybrid sweetgums to better understand herbicide efficacy on competition control and crop damage with a relative lack of a quiescent period.
- Fertilization and prescriptions that may help compensate productivity under drier conditions….e.g. increased or maintained growth is possible with improved soil nutrition.
- Landowner perceptions about supplying woody biomass for wood-based bioenergy (most are in favor of supplying biomass for bioenergy).
- Forest landowner willingness to manage forests for carbon sequestration in the South. (Most landowners (55%) would participate if they receive meaningful profit.)
- Short rotation wood crop production with poplar, sweetgum, eucalyptus.

Key Knowledge Gaps

- Impact of invasive species on crop production and silvicultural practices.
- Potential economic performance of forest management in future variable climatic conditions.
- Baseline stand-level growth models, coupled with general response functions for thinning, competing vegetation control, and fertilizer applications to better provide accurate estimates of pine plantation productivity for varying levels of management intensity.
- Modifying current pine site index values to biophysical variables (soils and climate) used to incorporate the effects of climate in tree growth 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.
- Tree productivity variability indices with climate, soils, stand development, and management factors.
- 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.
- Modeling the quiescent period for loblolly pine, now and in the future, and how it impacts planting parameters, herbicide use, and success.
- Improved herbicide/vegetation control options and prescriptions, given greater climate variability, that more carefully dial-in rates, timing, and chemistry to maintain/improve control of unwanted plants without further stressing crop trees.
- Response rate indices of pine and hardwood plantations to fertilization under continued increases in atmospheric CO_2 (which itself has a fertilization effect) and precipitation variability.

- Identification of the best seed source for major timber producing species that will best resist impacts of climate change/variability.
- Guidelines for stocking and stand density that more closely aligns the biological requirements of crop trees under changing climate variability with market demand and operational requirements, insect and disease threats.
- Hardwood forests are more prized for their ecosystem service values in this region. Additional knowledge and concomitant management strategies about climate change impact to growth, survivability and wildlife mast outputs is crucial. Similarly, for woody species protecting farm fields, livestock and farmsteads.

When considering traditional timber production, the Western Gulf/Southern Plains region is uniquely challenged because the region already experiences the hottest conditions and lowest precipitation compared to other regions with the same timber producing species. Climate change will likely worsen drought conditions to the greatest extent in this region. Recent rainfall reduction studies indicate that the decrease in plantation growth under dryer conditions may be mitigated, at least in part, through aggressive nutritional management (i.e., the proper application of fertilizer) because higher nutrient status increases water use efficiency. And while climate change has marginal effects on productivity, greater risk probably lies with increased insect, pathogen, and wildfire outbreaks. Good forest management using updated silvicultural parameters will become more and more important.

Arthropod Pests and Plant Diseases

Phillip Mulder

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Introduction

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, the same relationship does not necessarily exist for many plant pathogens.

Current Knowledge

Intuitively, most people realize that insects and plant pathogens do not exert their harmful and/or beneficial effects independently but may act together or synergistically to optimize their influence on plants and/or animals. In contrast, control mechanisms for both types of organisms are not approached in the same manner. Intervention with insecticides for arthropod control are generally based on reaching specific thresholds for pest populations based on established economic considerations. Essentially, this approach is considered a rescue treatment that attempts to decrease damaging arthropods from reaching an economic-injury level, where the cost of control is equal to the loss in production. While some plant disease models use advisory thresholds that indicate when increasing levels of plant pathogens are building to a damaging level, the ensuing epidemiology of the disease may be limited based on climatic conditions. Therefore, rather than a rescue treatment to reduce inoculum, plant pathologists recommend fungicides or other disease-suppressing mechanisms (e.g., seed protectants) to protect healthy plant tissue. A common analogy used by plant pathologists, is the approach of painting a fence to essentially protect the wood from degradation.

Similar to interactions that occur between plant (or animal) diseases and arthropod populations is the relationship between plant communities and global climate shifts. These shifts are likely to affect agroecosystems in several ways, but the outcome, as a shift in productivity, may depend on the combined effects of climate (temperature and precipitation), other global influences, and even changes in vegetative profile within a given area. Because of the cosmopolitan distribution of arthropod and plant diseases across a wide gamut of potential hosts, the influence of vegetative shifts cannot be ignored as contributors to insect and/or disease outbreaks. Warming accelerates plant development, but it can reduce grain-fill, reduce nutrient-use efficiency, increase crop water consumption, and favors C_4 plants over C_3 crops (Fuhrer 2003). Warmer climates also favor accelerated insect development and winter survival, and can cause significant shifts in northern latitudes in arthropod and plant disease phenology in relationship to reproduction and growth (Bale et al. 2002, Porter et al. 1991, Patterson et al. 1999). Abiotic effects brought on by global warming include: water vapor changes and increased atmospheric CO_2, CH_4, N_2O and O_3, which can partly trap reflected radiation, thereby warming surface temperatures (the greenhouse effect).

Simple global climate change models often neglect disturbance ecology and the effects of other influences (e.g. fire,) that may disrupt insect and plant diseases and potential resources required by these organisms in completing development (Scasta et al. 2017). In addition, anthropogenic influences (industry, fossil fuels, changes in tillage practices, etc.) may further exacerbate the effects of changes in climate and radiative active gases on crop production and accompanying pest species. In response to unusually hot summers, certain species of insects in the Orders Odonata (damselflies and dragonflies), Orthoptera (grasshoppers), and Lepidoptera (caterpillars) in northwestern Europe have already expanded their normal range (Cannon 1998). In addition, retention of stubble through widespread adoption of conservation or minimum tillage practices has caused considerable increases in plant pathogenic inoculum, leading to increased severity of *Fusarium* head blight and crown rot, particularly under unseasonably dry conditions (Chakraborty et al. 2006). These two plant pathogens affect crown, basal stem, and root tissue in most cereal-producing countries. In turn, increased incidence of *Fusarium* — more than crown rot — can significantly increase mycotoxin contamination of grains (Chakraborty and Newton 2011). Infected host tissues have been associated with chronic and fatal toxicosis of humans and animals (Desjardins 2006). In forage species, increased lignification brought on by warmer conditions may positively affect plant resistance to fungal attack (Fuhrer 2003). Similar to insect pests, however, impact models predict that higher winter temperatures may favor pathogen survival and, in turn, increase the amount of initial inoculum present. In contrast, drier conditions in summer would reduce the risk of infection by pathogens that require leaf wetness or wet soils for infection (Fuhrer 2003).

Warming climates can affect insect life cycles and geographical range changes; shorten insect generation times; modify host physiology and/or chemical composition; increase overwintering capability; influence crop-pest synchronization, insect dispersal and migration; decrease or increase the availability of host plants; and ultimately decrease or increase the numbers of predators, parasitoids, competitors, and insect pathogens that impinge on insect pests. In maize, losses due to insect pests and costs of controlling them represent the largest allocation of resources in the production of this crop worldwide. Several key pests of maize contribute to a significant portion of these losses and costs (Oerke et al. 1994). The corn rootworm complex (*Diabrotica* spp.) alone is estimated to cost producers in the U.S. approximately $1 billion annually (Metcalf 1986). Other serious insect pests include the European corn borer, *Ostrinia nubilalis,* and the corn earworm, *Helicoverpa zea*. Potential distribution range for these insects, under increasing warmer temperature regimes, would expand prevalence of the corn earworm into the Northeast and Upper Midwest, as well as California and the Columbia Basin in eastern Washington (Diffenbaugh et al. 2008). The potential range of the European corn borer under warming climate scenarios would encompass the entire continental U.S., but it is already well distributed throughout the cornbelt. Likewise, the potential range of rootworms in corn would follow a similar trend to that seen with the European corn borer. The greatest change in potential range from any of these three pests would be with the corn earworm, a cosmopolitan pest. Expansion of this species into the Upper Midwestern U.S., a key region of global maize production, could have profound effects on management of the species in other hosts as well (soybeans, tomato, etc.) (Stinner et al. 1989). Further compounding this problem would be the wide range of insecticide resistance exhibited by this insect. While expansion of the European corn borer range may not change considerably, the increase in growing degree days (GDD) over a growing season could provide an increase in damage by the production of an additional generation (Fleming and Volney 1995). In the case of the rootworm complex, relaxed cold limitation would reduce overwintering mortality and allow this species to become prevalent in new areas at higher latitudes (Diffenbaugh et al. 2008).

In addition to effects of diseases and insect pests on plants, recent studies have begun to explore the effects of warming climate scenarios on arthropods affecting livestock. Scasta et al. (2017) in a five-year study explored the effects of climate extremes on vegetative change and the decoupling of the interaction of fire-grazing processes in relationship to fly parasitism of cattle. Another author has suggested that climate change models have predicted up to a 244% increase in filth flies in Europe (Ghoulson et al. 2005). This increase is driven by temperature and rainfall. Parasitic external flies are considered the most damaging parasites of grazing livestock, causing more than $2 billion in economic losses annually in the U.S. (Byford et al. 1992). These losses are associated with loss of blood, avoidance behavior, reduced grazing time, and disease exposure (Boland et al. 2008). Accompanying these problems is the rapid development of resistance to insecticides and the lack of alternative control strategies. Regular prescribed burning and allowing fire to help reduce cattle parasite load, specifically horn flies, *Haematobia irritans*, and face flies, *Musca autumnalis*, can alter vegetation structure and the parasitic fly composition of cattle herds. In their five-year study, Scasta et al. (2017) showed how early spring warming experienced in Iowa in 2012 predicted and actually resulted in an extra early emergence of horn flies that was statistically earlier than any other year during their studies. In comparison to each year, predicted and observed emergence of this pest occurred nearly one month earlier than every other year and in some cases, nearly five weeks (2013) before the predicted calendar date. High temperature was the weather variable most strongly explaining intra-annual horn fly population dynamics, while precipitation was a poor indicator. By managing woody plant cover using fire, they also showed that vegetative structure alone explained 50% and 60% of the variation of herd fly load for horn flies and face flies, respectively. Lessons learned from these seminal studies suggest that under increasing temperatures, producers should expect increased populations of horn flies and face flies, that the influence of climate and vegetation change on these pests may be relevant to situations beyond livestock parasites, and that vegetation structure, especially reducing woody plants, may be a proactive approach to livestock external parasite management. While this study, over a five-year period, does not depict repeated results over say a 20-year scenario, it does elucidate clearly how livestock producers might help in mitigating the effects of external parasites on their animals and provide them with additional control strategies when warming climatic conditions encroach into their area earlier than anticipated. This is extremely important when considering early application of insecticide-impregnated ear tags, which have a history of horn fly resistance problems associated with early use. Application of tags was first developed for managing ear ticks, and while these pests are currently adequately controlled using these products, early use may lead to a plethora of problems with managing these and other livestock pests.

In general, most studies agree that future climate changes are likely to produce an increased challenge to agriculture from insect and disease pests; however, there are varying opinions on the overall impact from these organisms over gradually changing conditions (Brignall et al. 1994). For many species, rare and extreme weather events could be more important than long-term trends in climate change (Fleming and Volney 1995). From an evolutionary perspective, large-scale climatic fluctuations have occurred and the insect fossil record suggests that "insects have seen it all before" (Lawton 1995); however, the current rate of change in CO_2 levels is unprecedented (Vitousek 1994). What these changes mean to modern farming and ranching may dictate better management and consideration of alternative control measures within the context of the surrounding landscape.

Key Knowledge Gaps

Research:

- Long-range research trials to ascertain the effects of climate changes on insect and plant disease problems. This would entail 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 insect and plant disease range expansion, overwintering capacity, generational time, etc., would impact agricultural costs and returns.
- Evaluate alternative climate change scenarios to examine their expected effects on soil-inhabiting insects and plant diseases in the rhizosphere surrounding host plants.
- Continued examination of the effects of rare and/or extreme weather events on insect and plant disease epizootics (e.g. immigration and emigration, survival, etc.); in particular how does a combination of such events (e.g. fewer cold spells in winter followed by drought in spring or summer) affect outbreaks.
- Closely examine how changes in carbon:nitrogen concentration ratios caused by elevated CO2 affect plant pathogens, insects, or their plant hosts (e.g. lignification).

Extension:

- Develop forecasting tools within the system to help producers be more proactive to changing environmental conditions.
- Expand and use 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.
- With an eye on future generations, develop a portfolio of social media and electronically based approaches (e.g. apps, blogs, etc.) for providing information to the agricultural sector.
- Continued execution of research and extension related to expected impacts of extreme weather events and climate change in a clear, transparent, unbiased, and nonpartisan manner.

Citation information is available from authors.

Economic Drivers

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Introduction

For the purposes of this white paper, the Southern Plains region of the U.S. will focus primarily on the rural portions of Kansas, Oklahoma and Texas. In addition, the primary agricultural and natural resources sectors that comprise significant portions of the rural economy in the Southern Plains are categorized as: irrigated agriculture; dryland agriculture; grazing; livestock and dairy production; and forestry.

To be able to understand, and possibly develop policies and actions to address the sustainability of the agricultural and natural resource economies in the Southern Plains requires that the sectors of the economy be understood as an interconnected system that is being influenced by external forces and resource constraints. Thus, in addition to increasing our knowledge on the behavior of each sector, we must also focus on understanding the interrelationship and interdependencies between sectors, as well as determining the significant constraints and exogenous factors that force change upon the agricultural and natural resource economies within the region.

Current Knowledge

There has already been a great deal of research related to understanding the interdependence of each of the agricultural and natural resource sectors from an economic perspective, primarily led by researchers in the agricultural economics disciplines. In addition, there has been a significant amount of research initiated by physical geographers and rural sociologists evaluating land use changes/trends over time in the region. Much of this research has led to the creation of geospatial data sets containing information on land use condition and change, especially within the last three decades when satellite imagery became more readily available. However, there has been little linkage between these two areas of research that are in essence addressing the same fundamental question, which is "How are agricultural and natural resource sectors changing over time within the region?" Linking these two areas of research could yield significant increases in understanding the interdependency of the agricultural and natural resources sectors within the region, and possibly lead to developing better tools to analyze the impacts of changes in practices and policies within the region.

There are a number of resource constraints and exogenous forces that affect the agricultural and natural resource sectors within the Southern Plains. These include the region's climate, availability of water resources, growth of population centers, and technological advances in the productivity of agricultural lands. Of these, the factor that will most prominently affect the agricultural and natural resource sectors within the region is the availability of water resources, especially for irrigated agriculture. The vast majority of irrigated agriculture within the region is supplied using groundwater resources, either from the Ogallala Aquifer, or from smaller alluvial aquifers adjacent to surface streams. Over the last several decades, it has become clear that these groundwater resources are being depleted, with some areas of the Ogallala Aquifer experiencing water level declines of over 100 feet, and many areas of the aquifer not having enough saturated soil to maintain productive groundwater wells. In addition, use of groundwater from alluvial aquifers has led to significant declines in the base flow of adjacent streams. In states such as Kansas where surface and groundwater rights are conjunctively administered, water rights associated with stream diversions are most often superior to those associated with groundwater pumpage. Thus, when stream flows become depleted, groundwater pumpage must often be curtailed.

No matter what the circumstance, it is clear that there will be less water available for irrigated agriculture across the region in the future. This issue has been addressed through increasing the efficiency of water use for crop production, both in terms of increasing the efficiency of water application by irrigation systems, as well as developing crops that produce more with less water. These efforts are best described as creating "more crop per drop" to help extend groundwater resources across the region. However, there is a limit to how far these technological

innovations can help in supporting irrigated agriculture in the future, and it is clear that there will be a continued reduction in irrigated acreage across the region as groundwater resources continue to be depleted. This reduction in irrigated agriculture will impact all of the agricultural and natural resource sectors in the Southern Plains. A reduction in irrigated agriculture across the region could lead to declines in feedstocks for the dairy and livestock sectors, which would result in a decline in productivity of this sector. A reduction in irrigated agriculture could also result in declines of exports to food storage, processing and distribution centers, which would also imply an overall decline in economic activity for the region. This could paint a bleak economic picture unless efforts are undertaken to rethink the relationships between water use and the agricultural and natural resource economies of the region.

Key Knowledge Gaps

Future research efforts and activities should move beyond its current focus on "more crop per drop" and increase its focus on deriving more economic and social value of water use across the region and 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 with a strong transportation system that enhances to 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.

Notes

Notes

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

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