Economic Impacts of Climate Change on Kansas

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A Review and Assessment Conducted by
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INTRODUCTION

Policymakers across the country are now seeking solutions to curb greenhouse gas emissions and to help us adapt to the impending impacts triggered by past emissions. The debate to date has primarily focused on the perceived costs of alternative solutions, yet there can also be significant costs of inaction. Climate change will affect our water, energy, transportation, and public health systems, as well as state economies as climate change impact a wide range of important economic sectors from agriculture to manufacturing to tourism. This report, part of a series of state studies, highlights the economic impacts of climate change in Kansas and provides examples of additional ripple effects such as reduced spending in other sectors and resulting losses of jobs, wages, and even tax revenues.

A Primer on Climate Change

Earth's climate is regulated, in part, by the presence of gases and particles in the atmosphere which are penetrated by short-wave radiation from the sun and which trap the longer wave radiation that is reflecting back from Earth. Collectively, those gases are referred to as greenhouse gases (GHGs) because they can trap radiation on Earth in a manner analogous to that of the glass of a greenhouse and have a warming effect on the globe. Among the other most notable GHGs are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and chlorofluorocarbons (CFCs). Their sources include fossil fuel combustion, agriculture, and industrial processes.

Each GHG has a different atmospheric concentration, mean residence time in the atmosphere, and different chemical and physical properties. As a consequence, each GHG has a different ability to upset the balance between incoming solar radiation and outgoing long-wave radiation. This ability to influence Earth's radiative budget is known as climate forcing. Climate forcing varies across chemical species in the atmosphere. Spatial patterns of radiative forcing are relatively uniform for CO2, CH4, N2O and CFCs because these gases are relatively long-lived and as a consequence become more evenly distributed in the atmosphere.

Steep increases in atmospheric GHG concentrations have occurred since the industrial revolution (Figure 1). Those increases are unprecedented in Earth's history. As a result of higher GHG concentrations, global average surface temperature has risen by about 0.6°C over the twentieth century, with 10 of the last 12 years likely the warmest in the instrumental record since 1861 (IPCC 2007).

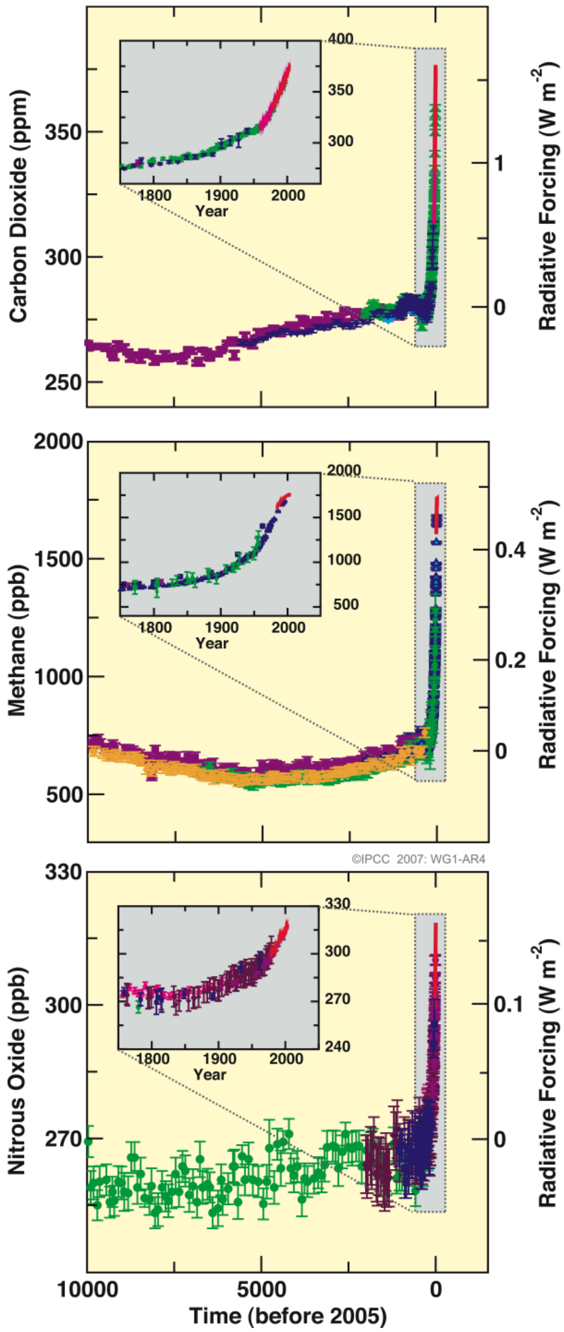


Figure 1: Atmospheric Concentrations of Carbon Dioxide, Methane and Nitrous Oxide
(Source: IPCC 2007)

A change in average temperatures may serve as a useful indicator of changes in climate (Figure 2), but it is only one of many ramifications of higher GHG concentrations. Since disruption of Earth's energy balance is neither seasonally nor geographically uniform, effects of climate disruption vary across space as well as time. For example, there has been a widespread retreat of mountain glaciers during the twentieth century. Scientific evidence also suggests that there has been a 40 percent decrease in Arctic sea ice thickness during late summer to early autumn in recent decades and considerably slower decline in winter sea ice thickness. The extent of Northern Hemisphere spring and summer ice sheets has decreased by about 10 to 15 percent since the 1950s (IPCC 2007).

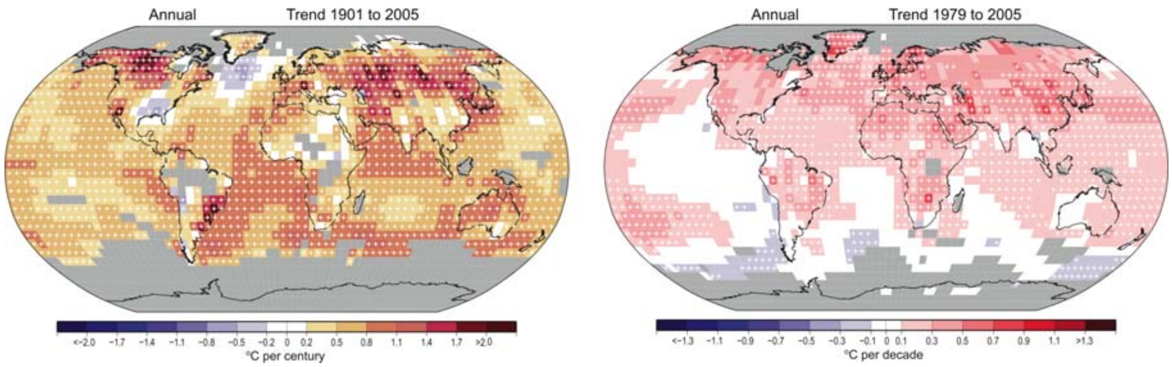


Figure 2: Annual Temperature Trends (Source: IPCC 2007)

The net loss of snow and ice cover, combined with an increase in ocean temperatures and thermal expansion of the water mass in oceans, has resulted in a rise of global average sea level between 0.1 and 0.2 meters during the twentieth century, which is considerably higher than the average rate during the last several millennia (Barnett 1984; Douglas 2001; IPCC 2001).

Changes in heat fluxes through the atmosphere and oceans, combined with changes in reflectivity of the earth's surface and an altered composition of may result in altered frequency and severity of climate extremes around the globe (Easterling, et al. 2000; Mehl, et al. 2000). For example, it is likely that there has been a 2 to 4 percent increase in the frequency of heavy precipitation events in the mid and high latitudes of the Northern Hemisphere over the latter half of the twentieth century, while in some regions, such as Asia and Africa, the frequency and intensity of droughts have increased in recent decades (IPCC 2001). Furthermore, the timing and magnitude of snowfall and snowmelt may be significantly affected (Frederick and Gleick 1999), influencing among other things, erosion, water quality and agricultural productivity. And since evaporation increases exponentially with water temperature, global climate change-induced sea surface temperature increases are likely to result in increased frequency and intensity of hurricanes and increased size of the regions affected.

Impacts of Climate Change throughout the US

This study on the economic impacts of climate change in the State of Kansas is part of a series of state-focused studies to help inform the challenging decisions policymakers now face. It builds on a prior assessment by the Center for Integrative Environmental Research, US Economic Impacts of Climate Change and the Costs of Inaction, which concluded that throughout the United States, individuals and communities depend on sectors and systems that are expected to be greatly affected by the impacts of continued climate change.

- The agricultural sector is likely to experience uneven impacts throughout the country. Initial economic gains from altered growing conditions will likely be lost as temperatures continue to rise. Regional droughts, water shortages, as well as excess precipitation, and spread of pest and diseases will negatively impact agriculture in most regions.

- Storms and sea level rise threaten extensive coastal infrastructure – including transportation networks, coastal developments, and water and energy supply systems.

- Current energy supply and demand equilibria will be disrupted as electricity consumption climbs when demand grows in peak summer months. At the same time, delivering adequate supply of electricity may become more expensive because of extreme weather events.

- Increased incidence of asthma, heat-related diseases, and other respiratory ailments may result from climate change, affecting human health and well-being.

- More frequent and severe forest fires are expected, putting ecosystems and human settlements at peril.

- The reliability of water supply networks may be compromised, influencing agricultural production, as well as availability of water for household and industrial uses.

As science continues to bring clarity to present and future global climate change, policymakers are beginning to respond and propose policies that aim to curb greenhouse gas emissions and to help us adapt to the impending impacts triggered by past emissions.

While climate impacts will vary on a regional scale, it is at the state and local levels where critical policy and investment decisions are made for the very systems most likely to be affected by climate change – water, energy, transportation and public health systems, as well as important economic sectors such as agriculture, fisheries, forestry, manufacturing, and tourism. Yet, much of the focus, to date, has been on the perceived high cost of reducing greenhouse gas emissions. The costs of inaction are frequently neglected and typically not calculated. These costs include such expenses as rebuilding or preparing infrastructure to meet new realities and the ripple economic impacts on the state's households, the agricultural, manufacturing, commercial and public service sectors.

The conclusions from our nation-wide study highlight the need for increased understanding of the economic impacts of climate change at the state, local and sector level:

- Economic impacts of climate change will occur throughout the country.
- Economic impacts will be unevenly distributed across regions and within the economy and society.
- Negative climate impacts will outweigh benefits for most sectors that provide essential goods and services to society.
- Climate change impacts will place immense strains on public sector budgets.
- Secondary effects of climate impacts can include higher prices, reduced income and job losses.

Methodology

This report identifies key economic sectors in Kansas which are likely affected by climate change, and the main impacts to be expected for these sectors. The report provides examples of the direct economic impacts that could be experienced in the state and presents calculations of indirect effects that are triggered as impacts on individual sectors in the economy ripple through to affect others.

The study reviews and analyzes existing studies such as the 2000 Global Change Research Program National Assessment of the Potential Consequences of Climate Variability and Change which identifies potential regional impacts. Additional regional, state and local studies are used to expand on this work, as well as new calculations derived from federal, state and industry data sources. The economic data is then related to predicted impacts of climate change provided from climate models. To standardize the results, all of the figures used in this report have been converted to 2007 dollars (BLS 2008).

Since the early 1990s, and especially during the 21st century, significant progress has been made in understanding the impacts of climate change at national, regional, and local scales. The Canadian and Hadley climate change models are cited most frequently and we look first to these, yet there are many other valuable models used by some of the specialized studies we cite in this report.

In addition to looking at data that illustrates the direct economic impacts of climate change, the report also provides examples of the often overlooked ripple economic effects on other sectors and the state economy. To calculate these, we employed a modified IMPLAN™ model from the Regional Economic Studies Institute (RESI) of Towson University. This is a standard input/output model and the primary tool used by economists to measure the total economic impact by calculating spin-off impacts (indirect and induced impacts) based upon the direct impacts which are inputted into the model. Direct impacts are those impacts (jobs and output) generated directly by the project. Indirect economic impacts occur as the project (or business owners) purchase local goods and services. Both direct and indirect job creation increases area household income and results in increased local spending on the part of area households. The jobs, wages, output and tax revenues created by increased household spending are referred to as induced economic impacts.

After reviewing climate and economic information that is currently available, the study identifies specific data gaps and research needs for further understanding of the significant economic impacts. There is no definitive total cost of inaction. Given the diversity in approaches among existing economic studies and the complexity of climate-induced challenges faced by society, there is a real need for a consistent methodology that enables more complete estimates of impacts and adaptation costs. The report closes with basic recommendations and concluding lessons learned from this series of state-level studies.

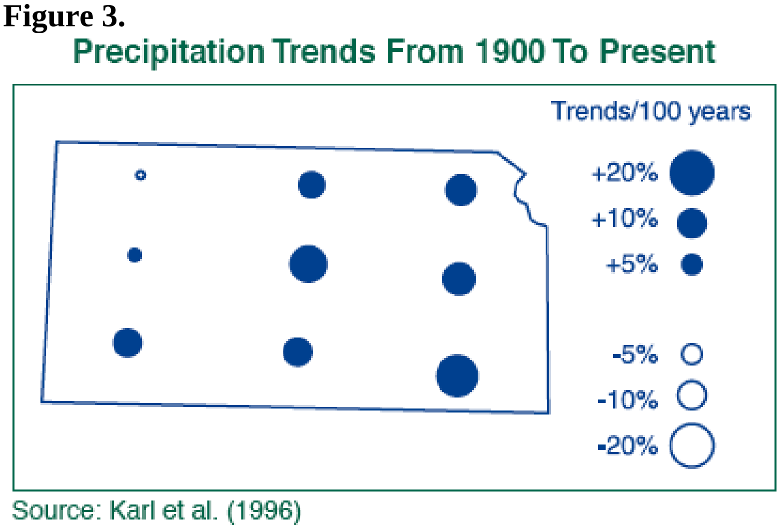
Not all environmentally induced impacts on infrastructures, economy, society and ecosystems reported here can be directly or unequivocally related to climate change. However, historical as well as modeled future environmental conditions are consistent with a world experiencing changing climate. Models illustrate what may happen if we do not act now to effectively address climate change and if adaptation efforts are inadequate. Estimates of the costs of adapting environmental and infrastructure goods and services to climate change can provide insight into the very real costs of inaction, or conversely, the benefits of maintaining and protecting societal goods and services through effective policies that avoid the most severe climate impacts. Since it is typically at the sectoral and local levels where those costs are borne and benefits are received, cost estimates can provide powerful means for galvanizing the discussion about climate change policy and investment decision-making.

These cost estimates may understate impacts on the economy and society to the extent that they simply cover what can be readily captured in monetary terms, and to the extent that they are calculated for the more likely future climate conditions rather than less likely but potentially very severe and abrupt changes. The broader impacts on the social fabric, long-term economic competitiveness of the state nationally and internationally, changes in environmental quality and quality of life largely are outside the purview of the analysis, yet likely not trivial at all. Together, the monetary and non-monetary, direct, indirect and induced costs on society and the economy provide a strong basis on which to justify actions to mitigate and adapt to climate change.

CLIMATE CHANGE IN KANSAS

The climate of Kansas varies from the east to west; the eastern half receives more moisture from the Gulf of Mexico, while the western half has a semiarid climate (Wikipedia 2008). In the last century, precipitation has increased by 10-20 percent in the eastern part of Kansas (See Figure 3) (EPA 1998).

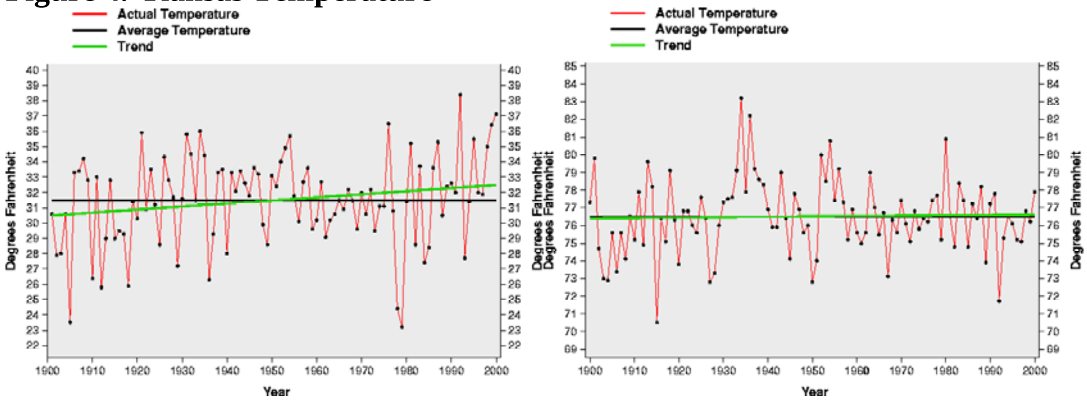
Figure 3.



Source: EPA 1998

According to NOAA records, the average winter temperature in Kansas increased by 2.1° F (1.2° C) from 1900 to 2000 (Figure 4). Over the same period, the average summer temperature increased by 0.3° F (0.2° C) (Figure 5) (NOAA 2007).

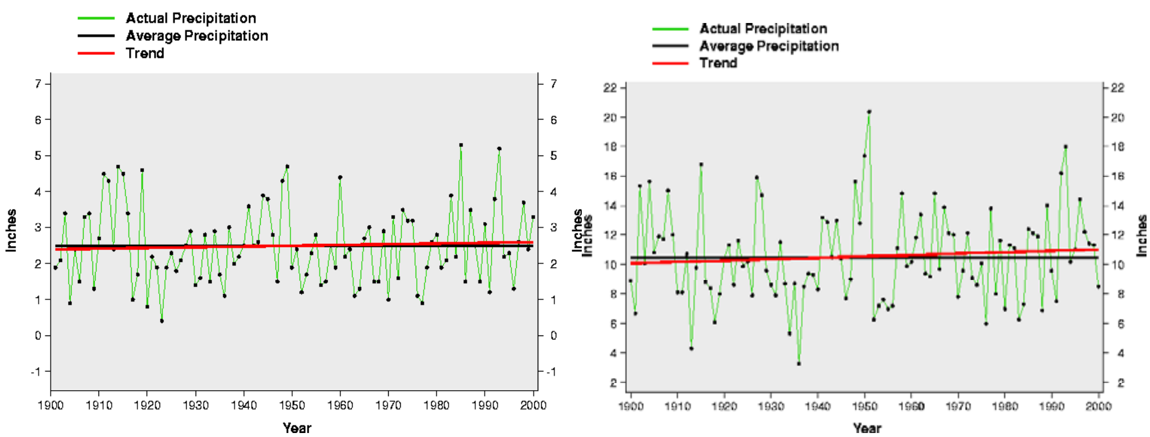
Figure 4. Kansas Temperature



Source: NOAA 2007

Between 1900 and 2000, the average winter precipitation in Kansas was 2.48 inches (6.30 cm). During that time, the average yearly precipitation increased by 0.1 inches (0.25 cm) (Figure 4). During the same period, the average total summer precipitation was 10.54 inches (26.77 cm). The average yearly precipitation increased by 0.8 inches (2.03 cm) over that time period (Figure 5).

Figure 5. Kansas Precipitation



Source: NOAA 2007

According to the Canadian and Hadley climate change models, expected future temperature change in Kansas should be roughly the same across the state. The two models concur on a 2-6° C increase minimum mean temperatures and a 0-6° C increase in maximum mean temperatures throughout Kansas over the next 30 years. The models diverge on the 90 year outlook: the Hadley model predicts increases of 4-8° C for both minimum and maximum mean temperatures, while the Canadian model predicts much higher temperature increases on the order of 10-16° C (Ojima and Lackett 2002).

The climate models predict changes in annual precipitation that vary geographically and temporally. The eastern half of the state could see increases in precipitation of up to 11 inches (28 cm) per year in the 2090-2099 timeframe (Ojima and Lackett 2002). The west will likely see a drying climate in the short and long term, but there is a high level of disagreement between models. The contrast between expected east and west precipitation changes due to climate change could have substantial implications for future water use and allocation patterns in the state of Kansas (Ojima and Lackett 2002).

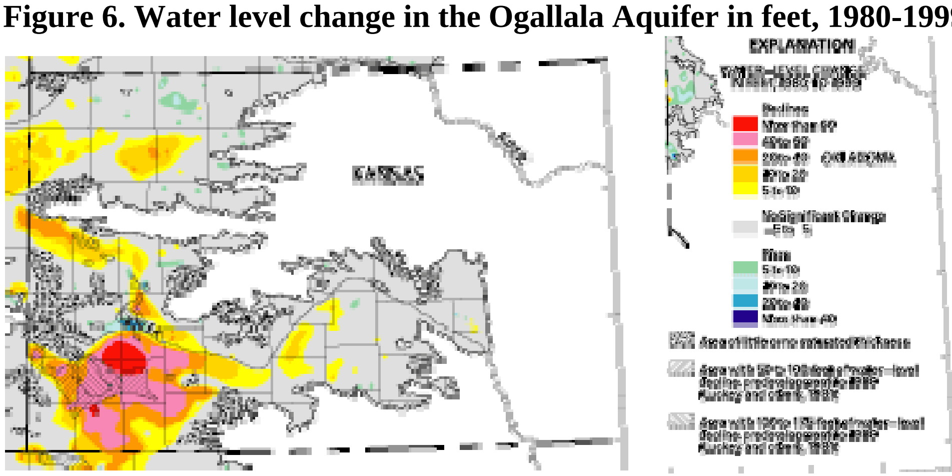
MAJOR ECONOMIC IMPACTS

The largest contributors to state GDP in Kansas are government and manufacturing. Kansas ranks sixth among states in agricultural exports, although the agricultural sector makes up only a small percentage of Kansas's GDP (NASS 2007; BEA 2007). Kansas grapples to allocate scarce water resources between irrigated farms and a growing urban population. Climate change could economically impact all of these areas.

Water Resources

Climate change will manifest the most significant effects on the water resources of Kansas (Keddema 2008). Most of western Kansas relies on groundwater from the Ogallala Aquifer for irrigation and potable water supply. Eastern Kansas, which contains most of the urban areas and livestock farms in the state, relies mainly on surface water from rainfall for its water supply (EPA 1998). Changes in precipitation patterns due to climate change, coupled with increasing demand for water from both urban areas and agriculture, could lead to problems in water allocation and quality.

Figure 6. Water level change in the Ogallala Aquifer in feet, 1980-1999.



Source: USGS, 2001, Water Level Changes in the High Plains Aquifer, 1980-1999.

Water rights in Kansas are categorized as junior and senior; those with senior water rights (i.e. agriculture and livestock rangeland) have priority over those with junior water rights (i.e. municipalities). An increasingly drier and warmer climate in the west will increase tension between junior and senior water rights holders (Ojima and Lackett 2002). Conflict has already arisen between Kansas and its neighbors over water: Colorado paid Kansas $29 million in damages for taking too much water from the Arkansas River in 2001, and Kansas has threatened

Nebraska with a similar lawsuit for violating water agreements on the Republican River (Kansas 2007, Hanna 2007). In addition, intense irrigation over the past 50 years has caused the water level in the Ogallala Aquifer to decline (USGS, 1995).

Flooding

On average, floods cause $33 million worth of damage in Kansas each year (Kansas 2007). Half of the major[1] floods since 1900 have occurred in the past 27 years (Kansas 2007). While fatalities due to flood events have decreased, economic damages from floods have increased because urban and agricultural developments have encroached on known floodplains (Kansas 2007). This land use trend coupled with more frequent flooding due to climate change will result in larger economic losses from each flooding event.

Flash floods pose serious threats to dry land that cannot absorb water quickly (Kansas 2007). The western part of the state will be increasingly susceptible to flash flooding as its climate becomes drier over the next century.

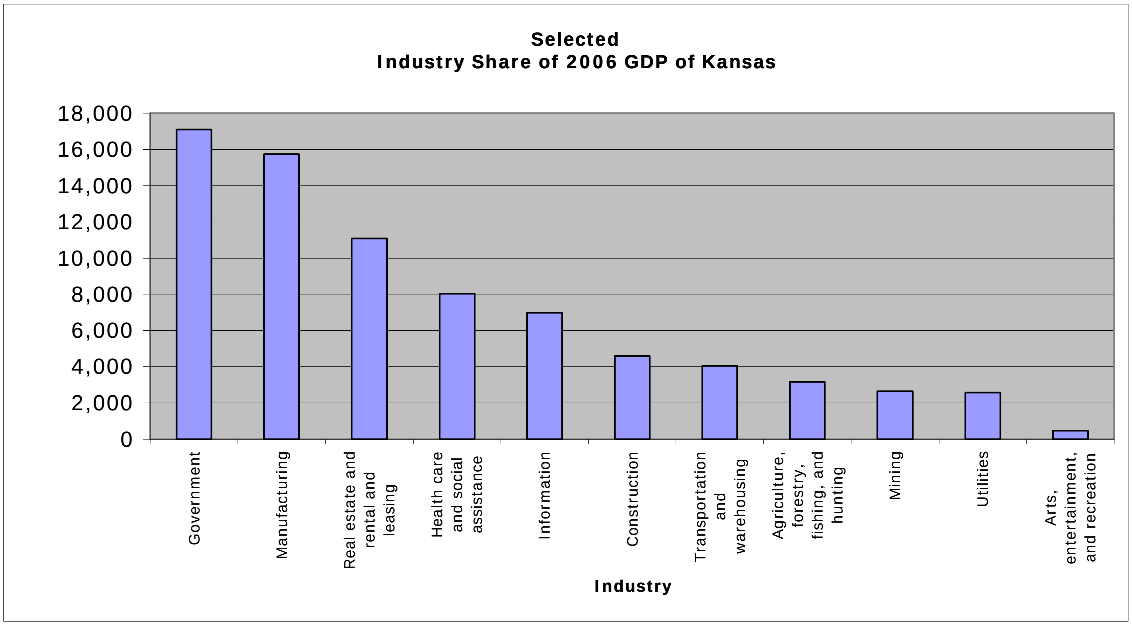
More frequent flooding events could also negatively impact water quality in the state of Kansas. Flooding would increase the levels of pollution and fertilizers in runoff from urban areas and farms, respectively (EPA 1998). There would also be higher costs associated with purifying water with increased pollution content.

Agriculture

Effects of climate change on the agriculture industry in Kansas could include increased incidence of flooding, improved conditions for invasive species, damage to crops and livestock from increased temperatures and lower precipitation, and changes in rangeland characteristics. Agricultural exports accounted for $3.29 billion (2007 dollars), about 3 percent, of the Kansas state GDP of $114 billion (2007 dollars) in 2006. The agriculture industry makes up about 2 percent of the workforce, or 40,000 jobs (US Census 2000). While the government and manufacturing sectors make up by far the largest shares of state GDP (Figure 7), farming has cultural and traditional significance to Kansas residents and when the industry suffers the effects reach beyond the crops and workers directly employed by farms.

[1] As defined by FEMA.

Figure 7. Kansas State GDP: Selected Industries (2006)



Source: US Bureau of Economic Analysis

An increased incidence of destructive flooding would have a negative impact on the agricultural sector, as well. One study by the Goddard Space Flight Center estimates that total US crop losses due to flooding could double over the next 30 years to $3.5 billion per year (2007 dollars) due to global warming (GSFC 2002). As Kansas farm products made up about 4.4 percent of the total market value of US crops in 2002, the approximate cost to Kansas from increased flooding would be about $150 million per year by 2032 (USDA-NASS 2002; CIER calculation). The effects of this increase in destructive flooding would cost Kansas $87 million per year in losses in other economic sectors and over 700 jobs per year (RESI 2008). Such impacts extend beyond the agricultural sector and could impact other sectors ranging from transportation to manufacturing.

One of the predictions of the Hadley and Canadian climate change models is higher average minimum temperatures. Studies have shown that changes in winter temperatures and precipitation can yield more favorable conditions for invasive species. USDA estimated that total crop losses across the US due to invasive species are about $17.3 billion (2007 dollars) annually (Ojima and Lackett 2002). Since Kansas makes up about five percent of cropland in the US, approximate losses due to invasive species in Kansas are about $871 million per year (USDA-NASS 2002; CIER calculation), or about eight percent of the total market value of Kansas crops in 2002 (2007 dollars) (USDA-NASS 2002). A one percent increase in the persistence of invasive species per year would cause $58 million in damages to other economic sectors and a loss of over 400 jobs in the agricultural and other economic sectors by 2017 (RESI 2008).

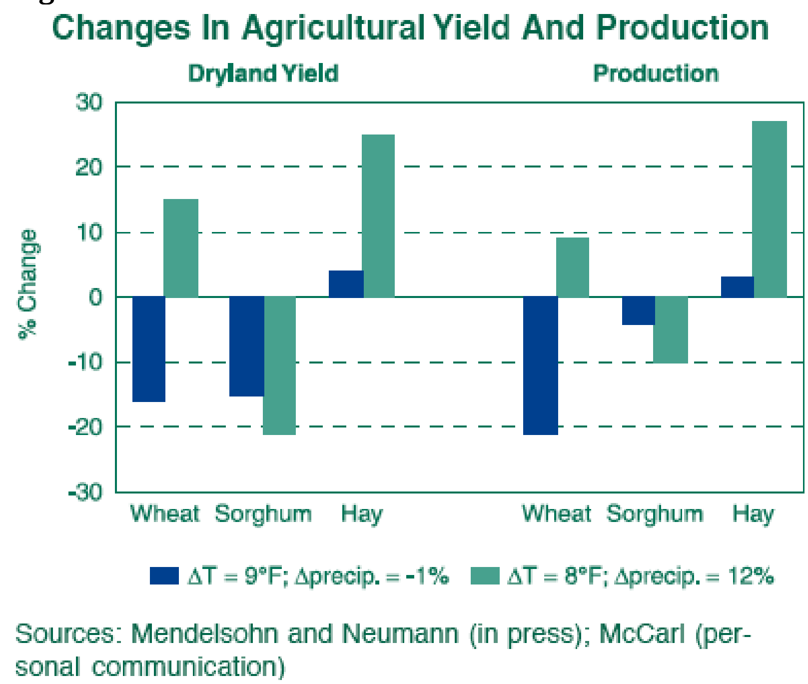
Higher summer temperatures due to climate change could shift crop production patterns northward (EPA 1998). This may force farmers to change which crops they grow, how much irrigation they use, or change what time of year they harvest crops. Also, the possibility of drier growing seasons will call for increased irrigation in the western part of the state, putting more pressure on an already strained groundwater supply (USGS 2001) and increasing the cost of operations on farms.

Changes in temperature could also affect livestock health and the cost of raising livestock. The market value of dairy products made in Kansas in 2002 was $281 million (2007 dollars) (USDA-NASS 2002). Only if temperatures rise significantly along with decreases in precipitation, pasture yields could deteriorate, livestock would gain less weight, and dairy cows may produce less milk (EPA 1998; PNAS 2007). According to a study by the National Academy of Sciences, dairy cow milk production in California could decrease by 11-22 percent by the end of the century due to warmer temperatures (PNAS 2007). The methods used in the study were adapted from research conducted in Sudan on Holstein cows (Ahmid and El Amin 1997). If the Sudan study can be applied to Holstein dairy cows in Kansas, the cost to Kansas dairy farmers could be between $31 and $62 million (2007 dollars) per year by the end of the century (CIER calculation).

Changes in the characteristics of rangelands due to climate change will be dependent on temperature, precipitation, and carbon dioxide levels (Ojima and Lackett 2002). Rangelands in different parts of Kansas could be affected differently depending on precipitation changes. Increasing CO_2 concentrations in the lower atmosphere could improve rangeland productivity in the near term (Ojima and Lackett 2002).

A study in the EPA report depicts climate change scenarios and their associated effects on wheat, sorghum and hay crop yields in Kansas (See Figure 8) (EPA 1998). The total value of all agriculture crops in Kansas in 2006 was $3.3 billion (2007 dollars) and wheat, sorghum, and hay comprised 70 percent of that total (NASS 2006). The study concludes that for a 9° F temperature rise and 1 percent decrease in precipitation, which is a possible situation in the western half of Kansas by 2035, the total crop value would decrease by 11 percent ($290.4 million 2007 dollars) (EPA 1998; Ojima and Lackett 2002; NASS 2006; CIER calculation). The effects throughout the Kansas economy of such a loss would amount to $169 million in other sectors of the state economy and a loss of nearly 1400 jobs overall (RESI 2008).

Figure 8.



Source: EPA 1998

OTHER ECONOMIC IMPACTS

Health

Climate change and air pollution could increase the incidence of ground level ozone, which contributes to illnesses such as asthma and respiratory inflammation. According to the EPA report, "a 2°F warming in the Midwest, with no other change in weather or emissions, could increase concentrations of ozone, a major component of smog, by as much as 8 percent" (EPA 1998). A study of the asthma-related morbidity and mortality in the Kansas City, Missouri metropolitan area found that direct and indirect expenditures on the treatment of asthma costs the cities of Overland Park, KS and Kansas City, KS over $13 million annually (Metropolitan Health Council, 2001). Direct medicine and health care costs for asthma and indirect costs due to missed work days for the state of Kansas totaled $105 million in 1998 (AAFA 1998).

In addition, higher temperatures will increase the use of air conditioners, placing greater demands on the energy infrastructure. As most of the household energy in Kansas comes from coal-fired power plants, increased use of air conditioners will create a positive feedback loop that increases the ground-level ozone problem.

Rising temperatures could increase the habitable area of vector- and rodent-borne diseases in the United States. Increasing temperatures have the potential to increase the length of the transmission season of Dengue fever in temperate regions such as Kansas. Multiples studies have shown a positive correlation between increased rainfall and the rodent population, which carries diseases such as the plague, hantavirus, and leptospirosis. A study modeling malaria risk and future climate change found no significant increase in malaria transmission risk in the United

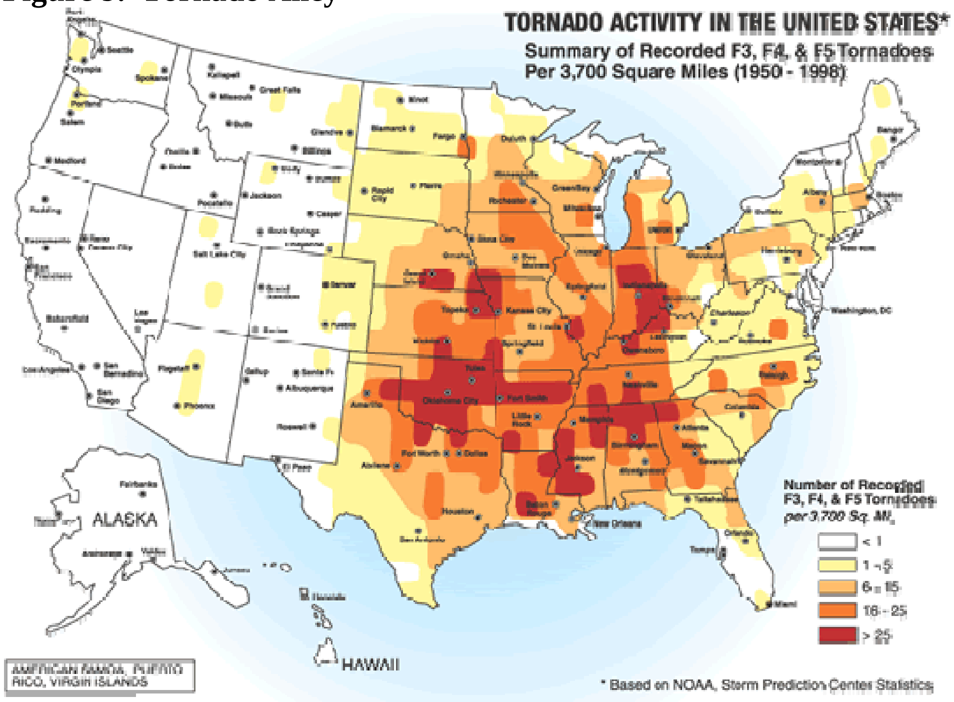
States, and warming may actually decrease the incidence of tick-borne diseases such as Rocky Mountain spotted fever. It should be noted that all of these studies modeled changes to the disease carrier population due to climate change and that transmission to humans is based on a number of other factors including behavior and activity choice. In other words, the increased risk to humans based on a larger disease carrier population is not one-to-one (Gubler et al 2001).

Severe Storms

Climate change models predict an increase in the intensity of storms in addition to changes in average temperatures and rainfall amounts. Strong and severe thunderstorms, sometimes with hail and tornadoes, are common in Kansas during the summer months. In 2007, the Kansas Hazard Mitigation Team ranked tornadoes as the number one hazard (out of 22) facing Kansas. Hailstorms were listed as number nine.

Tornadoes can occur almost anywhere in the United States, but they occur most often in "tornado alley:" the area of the country that stretches north from Louisiana to Minnesota, and east from Kansas to Kentucky (Figure 9). From 1950 to 2006, tornadoes caused $6.8 billion in damage to homes and agriculture, averaging $120 million per year (2007 dollars). In that same period, tornadoes caused 214 deaths and 2,617 injuries (Kansas 2007). An increase in the frequency and intensity of tornadoes because of climate change would cause extensive property and crop damage and loss of life. A one percent increase in the damage caused by tornadoes each year, a possible result of higher summer temperatures in Kansas (Francis and Hengeveld, 1998), for the next ten years would have extensive economic ramifications, including $2 million losses in agriculture and nearly $11 million in the buildings sector (RESI 2008). However, parts of the construction sector will benefits from flooding or the destruction of infrastructure as this sector will also be involved in the rebuilding effort. While jobs are created in the rebuild effort, those construction workers are not available to build new buildings and infrastructures. As a result, the state's infrastructure building stock cannot expand to accommodate new economic growth. The insurance sector may be impacted, but it would likely adjust its rates to reflect the new probabilities of flooding and storm damage, which, in turn, would divert disposable income from consumption to that sector.

Figure 9. Tornado Alley



Source: http://www.nesec.org/images/haz_tornado_alley.gif

Hail is another risk associated with severe thunderstorms. Stronger storms can produce larger hail in bigger quantities, increasing the destructive potential of storms. On average, hail causes approximately $46 million (2007 dollars) per year in property and crop damage in Kansas (Kansas 2007).

Tourism and Recreation

Diminishing or changing wildlife populations could affect some aspects of tourism and recreation, including hunting, fishing, and bird watching. In 2001 the fishing and hunting industries brought in $541 million (2007 dollars) in expenditures from both out-of-state tourists and Kansas residents (US Fish and Wildlife Service 2001). Kansas wetlands are a critical waypoint for migratory waterfowl: it is estimated that half of all migratory shore birds in the United States stop at Quivira National Wildlife Refuge in Stafford, Kansas (EPA 1998). Rising temperatures could shift the stopping point for these birds northwards, taking with it revenue from birdwatchers and nature enthusiasts. Deteriorating habitat due to climate change not only jeopardizes the wildlife populations but also a source of tourism revenue.

MISSING INFORMATION AND DATA GAPS

One of the significant costs to the state of Kansas due to climate change will come from the health impact. Although some studies correlate the effects of climate change with negative health impacts, there is incomplete data available on how those impacts translate to economic costs in terms of healthcare and decreased work productivity, for example.

Insurance costs to consumers will likely go up due to increasing variability of major weather events. A more complete view of the economic impact of climate change on Kansas should include a look at how insurance companies are likely to change their rates based on an increased frequency of floods, tornadoes, fires, and weather-related health problems.

CONCLUSIONS

Current and predicted climate trends in Kansas suggest that water supply will continue to be a major issue, especially in the arid west. Water shortages affect many industries including agriculture, power, and food processing, as well as municipalities. Industrial and municipal interests should evaluate the security of their water supplies and explore alternative options for obtaining water during dry periods.

Warmer temperatures, less precipitation in the west and more precipitation in the east will change the way the agricultural sector should operate. In light of predicted climate changes, farmers can evaluate what changes, if any, they should make to their crop types and harvest schedules. In the long term (in the next 80 years), dairy farmers should take measures to protect their cows from heat by planting trees, using water for cooling, or building artificial shelter.

The economic effects of changing ecosystems are not well understood. One effect of decreasing fish and game populations is lower revenue from tourism and recreation.

Higher summer temperatures might also place a strain on the electricity infrastructure due to increased use of air conditioning in homes and buildings. Kansas should encourage the use of renewable energy to meet this spike in demand to avoid increasing air pollution during hot summer months.

Lessons Learned

As we begin to quantify the potential impacts of climate change and the cost of inaction, the following five lessons are learned:

1. There are already considerable costs to society associated with infrastructures, agricultural and silvicultural practices, land use choices, transportation and consumptive behaviors that are not in synch with past and current climatic conditions. These costs are likely to increase as climate change accelerates over the century to come.

2. The effects of climate change should not be considered in isolation. Every state's economy is linked to the economies of surrounding states as well as to the national and global economy. While the economic costs of climate change are predicted to vary significantly from state to state, the negative impacts that regional, national and global markets may experience are likely to affect all states and many sectors.

3. While some of the benefits from climate change may accrue to individual farms or businesses, the cost of dealing with adverse climate impacts are typically borne by society as a whole.

These costs to society will not be uniformly distributed but felt most among small businesses and farms, the elderly and socially marginalized groups.

4. The costs of inaction are persistent and lasting. Benefits from climate change may be brief and fleeting -- for example, climate does not stop changing once a farm benefited from temporarily improved growing conditions. In contrast, costs of inaction are likely to stay and to increase.

5. Climate models and impact assessments are becoming increasingly refined, generating information at higher spatial and temporal resolutions than previously possible. Yet, little consistency exists among studies to enable "summing up" impacts and cost figures across sectors and regions to arrive at a comprehensive, state-wide result.

6. To provide not just a comprehensive state-wide assessment of impacts and cost, but to develop optimal portfolios for investment and policy strategies will require support for integrative environmental research that combines cutting-edge engineering solutions with environmental, economic and social analysis. The effort and resources required for an integrative approach likely pales in comparison to the cost of inaction.

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