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# Can conservation trump impacts of climate change on soil erosion? An assessment from winter wheat cropland in the Southern Great Plains of the United States

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A B S T R A C T

With the need to increase crop production to meet the needs of a growing population, protecting the productivity of our soil resource is essential. However, conservationists are concerned that conservation practices that were effective in the past may no longer be effective in the future under projected climate change. In winter wheat cropland in the Southern Great Plains of the U.S., increased precipitation intensity and increased aridity associated with warmer temperatures may pose increased risks of soil erosion from vulnerable soils and landscapes. This investigation was undertaken to determine which conservation practices would be necessary and sufficient to hold annual soil erosion by water under a high greenhouse gas emission scenario at or below the present soil erosion levels. Advances in and benefits of agricultural soil and water conservation over the last century in the United States are briefly reviewed, and challenges and climate uncertainties confronting resource conservation in this century are addressed. The Water Erosion Prediction Project (WEPP) computer model was used to estimate future soil erosion by water from winter wheat cropland in Central Oklahoma and for 10 projected climates and 7 alternative conservation practices. A comparison with soil erosion values under current climate conditions and conventional tillage operations showed that, on average, a switch from conventional to conservation tillage would be sufficient to offset the average increase in soil erosion by water under most projected climates. More effective conservation practices, such as conservation tillage with a summer cover crop would be required to control soil erosion associated with the most severe climate projections. It was concluded that a broad range of conservation tools are available to agriculture to offset projected future increases in soil erosion by water even under assumed worst case climate change scenarios in Central Oklahoma. The problem is not one of a lack of effective conservation tools, but one of adoption and implementation. Increasing the implementation of today's conservation programs to address current soil erosion problems associated with the large year-to-year climate variability in the Southern Great Plains would greatly contribute towards mitigation of projected future increases in soil erosion due to climate change.



## 1. Introduction

Controlling accelerated soil erosion by water in agricultural environments has been a problem since man began plowing the ground. Climate change adds an additional dimension to already existing soil erosion problems. A vast body of knowledge and experience on soil erosion, conservation practices, and conservation tools has been built over the past century. Conservationists can rely on this knowledge and available tools to search for effective soil erosion controls under a changing climate. A brief historical background on soil erosion work and successes is given below to provide an overview of the existing foundation and framework within which this interdisciplinary investigation on soil erosion

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and climate change is conducted. In the following, the word "soil erosion" implies sheet and rill erosion by water. Soil erosion by wind is outside the scope of this study.

Conservation of soil resources in the United States made significant strides during the 20th century. Led by Hugh Hammond Bennett and conservationists of the time, the Soil Erosion Service was established within the US Department of Agriculture (USDA) in 1933 (Bennett, 1939), which later became the Soil Conservation Service and more recently the Natural Resources Conservation Service (NRCS). This agency promoted the use of soil conservation practices such as construction of terraces, grasses waterways, contour tillage, and gully control structures (Ayres, 1936; Bennett, 1939) to control soil erosion, reduce sediment loss, and maintain soil productivity. The cultivation-revolution since the early 1980s brought about by the use of minimum tillage and no-till production systems, along with government programs, such as the Conservation Reserve Program that took highly erodible land out of crop production, led to additional significant improvements in soil conservation (US Department of Agriculture, 2013).

In 1982, the USDA conducted the first National Resource Inventory (NRI), which uses a statistical sampling technique to document land use, conservation practices, and erosion rates on non-federal lands across the United States. The survey has been repeated on an intermittent basis since that time. The NRI uses the Universal Soil Loss Equation (Wischmeier and Smith, 1978) to estimate soil loss rates at its sampling sites. The numbers reported indicate that soil erosion by water, on non-federal, cultivated croplands decreased by approximately 30% between 1982 and 2010 (based on data taken from US Department of Agriculture, 2013). These numbers only address sheet and rill erosion caused by water, and do not reflect soil erosion caused by water in ephemeral or permanent gullies, or by wind.

While conservation advances were made over the last century in the United States, the climate has also changed. Climate change impacts soil erosion rates by various pathways, of which primary ones include the drivers of rainfall, temperature, and atmospheric $CO_2$ concentrations, which impact biomass production and runoff, which in turn impact erosion rates (Fig. 1) (Walthall et al., 2012; Izaurralde et al., 2011; Nearing et al., 2004). Temperature may have either a positive or negative impact on biomass production, depending on the plant and its response to the temperature changes (Walthall et al., 2012). Atmospheric $CO_2$ concentrations and rainfall amounts and intensities are generally expected to have a positive correlation to plant biomass production, though the impact of rainfall can be negative in cases when intense storm events during the early growing season remove seedlings or when rainfall causes excessive soil moisture conditions that may either influence

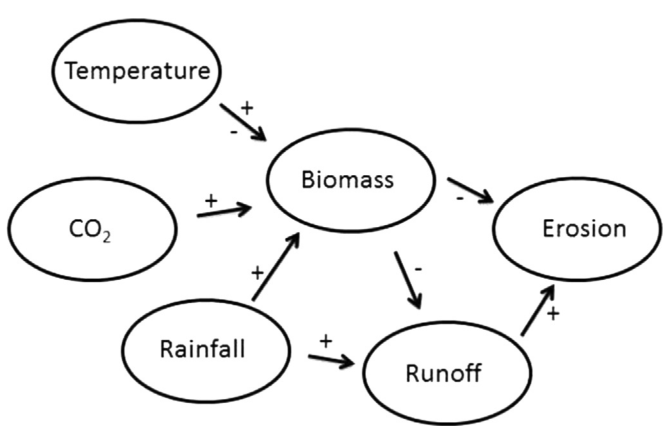


**Fig. 1.** Primary pathways by which climate change may impact rainfall-driven soil erosion, with most common correlation trends specified as plus or minus.

the timing of planting or plant growth under waterlogged soil conditions (Bassu et al., 2014; Walthall et al., 2012). Implicit in this generalized representation of the impacts of climate on erosion by water is that producers' response to climate change also will impact soil erosion rates (Delgado et al., 2013; O'Neal et al., 2005). Under climate change farmers will alter planting and harvest dates, as well as cultivars or crops produced because of changes in temperatures, soil moistures, and rainfall patterns (Walthall et al., 2012; Southworth et al., 2002; Pfeifer and Habeck, 2002).

Sustainable, high-yield crop production is critical to maintaining food security, especially during a time of climate change. Long-term sustainability of high crop yields requires soil management practices that promote soil function, soil quality, and soil health. Soil erosion adversely affects soil productivity by gradually depleting the soil of nutrients, fine soil particles, and water holding capacity. Degradation of soil aggregate stability also increases the risks of crusting and increased runoff. Soil conservation practices have proven effective in reducing soil erosion and maintaining soil productivity. However, climate change introduces a new dimension to the soil erosion problem. Soil erosion and conservation practices that were effective in the past may no longer be effective in the future. This question is examined for conditions in central Oklahoma.

Average temperature has increased over most of the contiguous United States in the last century and is expected to continue to do so this century and beyond (Melillo et al., 2014; Karl et al., 2009). Annual precipitation is also changing. Trends in winter and spring precipitation are projected to rise for the northern United States and decline in the Southwest (Peterson et al., 2013; AMS, 2013, 2012). In the Southern Great Plains, rising air temperature and changes in timing and magnitude of rainfall events have already been observed (Peterson et al., 2013; Higgins and Kousky, 2013; Groisman et al., 2012).

Rainfall amounts and daily rainfall intensities generally increased in the United States between years 1910 and 1996 (Karl and Knight, 1998). More than half of observed increases in total annual precipitation for the United States measured during that time were caused by increases in the frequency of heavy events, which were considered to be those in the upper 10 percentile of daily amount values. Also, the proportions of precipitation falling in heavy ( > 95th percentile), very heavy ( > 99th percentile), and extreme ( > 99.9th percentile) daily precipitation events increased during the years 1910 through 1999 by 1.7, 2.5, and 3.3% per decade, respectively, on average across the United States (Soil and Water Conservation Society, 2003). This is a pattern that appears to be occurring in many parts of the world (Groisman et al., 2005; Meehl et al., 2007). Changes in the water cycle propagate through the watershed system and affect processes such as runoff, foliar and ground cover production, soil erosion, sediment transport, and land productivity. Changes in rainfall timing, amount, intensity, and frequency, and minimum and maximum air temperature will inevitably impact the agricultural landscape (O'Neal et al., 2005; Karl and Knight, 1998). More intense and more frequent extreme rainfall events increase soil erosion, accelerate the degradation of soil quality, and diminish crop yields. Potentially large increases in soil erosion on cropland due to climate change are becoming a serious concern for farmers, land owners, and conservationist (Nearing et al., 2005; Zhang and Nearing, 2005; Soil and Water Conservation Society, 2003). Existing conservation practices may prove inadequate to manage soil erosion in light of projected climate change impacts (Melillo et al., 2014).

Assessing the effectiveness of current conservation practices under changed climatic conditions that are assumed to prevail in the future is a complex task that involves many climate and agronomic drivers, physiographic variables, interdependencies, and feed-back mechanisms (Delgado et al., 2011; Nearing et al.,