# INFLUENCE OF ELEVATED ATMOSPHERIC $CO_2$ AND TILLAGE PRACTICE ON RAINFALL SIMULATION

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## ABSTRACT

No work has investigated whether increasing atmospheric $CO_2$ concentration will impact sediment loss in agricultural systems. Rainfall simulation was conducted following a 10-year study investigating the effects of atmospheric $CO_2$ level (ambient and twice ambient) in two cropping systems (conventional tillage and no-tillage) on a Decatur silt loam (clayey, kaolinitic, thermic Rhodic Paleudults). The conventional system consisted of a sorghum [*Sorghum bicolor* (L.) Moench.] and soybean [*Glycine max* (L.) Merr.] rotation using spring tillage and winter fallow. The no-tillage system used this rotation along with three rotated cover crops [crimson clover (*Trifolium incarnatum* L.), sunn hemp (*Crotalaria juncea* L.), and wheat (*Triticum aestivum* L.)] without tillage. Elevated $CO_2$ increased residue in both tillage treatments, with the effect being greater under no-tillage. This resulted in increased water infiltration only under no-tillage. Overall, sediment loss was low under no-tillage regardless of $CO_2$ level; therefore, elevated $CO_2$ decreased sediment loss only under conventional tillage. Our results showed that both high $CO_2$ and no-tillage increased surface residues; this can improve water infiltration and reduce soil loss.

**Keywords:** global change, sediment loss, soil water infiltration, $CO_2$ enrichment

## INTRODUCTION

The global atmosphere is changing as evidenced by the well documented rise in atmospheric $CO_2$ concentration, which is expected to continue (Keeling and Whorf, 2001). Since $CO_2$ is a primary input to crop growth, there is interest in how this rise in $CO_2$ will impact highly managed agricultural systems. Over the last decade, numerous studies have demonstrated that elevated atmospheric $CO_2$ can result in greater biomass production (Amthor, 1995). The effect of elevated $CO_2$ on crop residue production can influence soil carbon dynamics in agroecosystems (Rogers et al., 1999; Torbert et al., 2000). Furthermore, soil carbon dynamics can be altered by management practices (e.g., fertility practices, tillage methods, and cropping systems including cover crops) (Kern and Johnson, 1993). There is, however, a lack of information on how elevated $CO_2$ will interact with management practices.

No work has investigated whether increasing atmospheric $CO_2$ concentration will impact sediment loss in agricultural systems. In the current study, crops were grown under different atmospheric $CO_2$ environments (ambient and twice ambient) and management conditions (conventional tillage and no tillage) for 10 years. Our objective was to conduct a rainfall simulation following this 10-year study to investigate treatment effect on soil sediment loss.

## MATERIALS AND METHODS

The experiment was conducted at the outdoor soil bin facility located at the USDA-ARS National Soil Dynamics Laboratory in Auburn, AL (Batchelor, 1984). This study was established in the fall of 1997 along the length of a bin (7m x 76m x 2m deep) filled with a Decatur silt loam soil (clayey, kaolinitic, thermic Rhodic Paleudults). Crops were grown from seed to maturity in open top chambers (Rogers et al., 1983) under ambient and twice-ambient atmospheric $CO_2$ levels in two crop management systems (conventional and no tillage). Carbon dioxide was supplied from a 12.7 Mg liquid receiver through a high volume dispensing manifold and the $CO_2$ level was elevated by continuous injection of $CO_2$ into plenum boxes as detailed in Mitchell et al. (1995).

This report covers a rainfall simulation following a 10-year elevated $CO_2$ study (1997-2007) comparing two crop management systems (conventional and no tillage). These crop management and crop rotation sequences have been previously described in detail (Prior et al., 2005). Briefly, the conventional system used a grain sorghum [*Sorghum bicolor* (L.) Moench. 'Pioneer 8282'] and soybean [*Glycine max* (L.) Merr. 'Asgrow 6101'] rotation with spring tillage and winter fallow. In the no-till system, grain sorghum and soybean were also rotated with three cover crops in the order of crimson clover (*Trifolium incarnatum* L. 'AU Robin'), sorghum, sunn hemp (*Crotalaria juncea* L. 'Tropic Sunn'), wheat (*Triticum aestivum* L. 'Pioneer 2684'), and soybean. The conservation system used "no-tillage" practices with no fallow periods. Fertility management practices followed local extension recommendations.

Prior to rainfall simulations, infiltration rates were estimated at three randomly selected locations in each plot using a mini-disk tension infiltrometer. Readings were made until a constant infiltration rate was achieved at 0.5 cm of tension.

A rainfall simulator was used to generate surface water runoff. Rainfall was created using a TeeJet ½ HH-SS50WSQ nozzle (Spraying System Co., Wheaton IL) approximately 2.5 m above the soil surface to achieve terminal velocity of water droplets (Sharpley and Kleinman, 2003). The rainfall simulator dimensions were 2.5 m long by 2.5 m wide. Prior to initiation, the simulator was calibrated to ensure a rate of ~100 mm $h^{-1}$ to generate runoff for 40 minutes. Once runoff was initiated, water samples were collected at 10 min intervals (0, 10, 20, 30, and 40 min). Flow rate was determined by recording the time to fill a 250 ml sample bottle at each sampling time. Runoff was pumped from the collection basin into a plastic tank. Upon simulation completion, tank volume was measured and cumulative water samples were collected. Background water source samples were also collected during each simulation event.

Runoff plots were established within the open-top chamber plots. Each runoff plot was 0.25 m by 0.25 m. Metal (3.2 mm thick) plot borders of the same dimensions were used to define the runoff plots. Three sides of each border extended above the soil surface to keep runoff water within the plot (border heights were 10.2 cm and were inserted to a depth of 7.6 cm), while the forth side was flush with the soil surface to allow flow of runoff water to a trough located on the downslope side of each plot. Immediately after collection, water samples were acidified with concentrated HCl and frozen until analyzed. Water samples were filtered through a 0.45-µm membrane to separate sediment. The soil sediment was then dried at 40°C prior to dry mass determinations. Soil samples were analyzed for C on a LECO TruSpec CN analyzer (LECO Corp., Saint Joseph, MI). All plant residue was collected from each rainfall plot at the end of the study and dried (55°C) prior to dry mass determination.

The experiment was conducted using a split-plot design with three replicate blocks. Whole-plot treatments (cropping system) were randomly assigned to half of each block. Split-plot treatments ($CO_2$ levels) were randomly assigned to one chamber each within each whole plot. Statistical analyses of data were performed using the Mixed Procedure of the Statistical Analysis System (Littell et al.,1996). A significance level of $P < 0.10$ was established *a priori*.

## RESULTS

Crop residue (lb $ac^{-1}$) was increased by both elevated $CO_2$ ($P < 0.001$) and no-till management ($P < 0.001$). There was a significant interaction between these two main effects treatments ($P = 0.006$) and was one of magnitude rather than direction. Residue was increased by elevated $CO_2$ in both no-till ($P < 0.001$) and conventional tillage ($P = 0.002$), but the increase was greater under no-till. Also, residue was increased by no-till in both ambient ($P < 0.001$) and elevated ($P < 0.001$) $CO_2$.

Water infiltration (in $h^{-1}$) was also increased by both elevated $CO_2$ ($P = 0.028$) and no-till management ($P = 0.070$). There was a significant interaction between these two main effects treatments ($P = 0.032$). Infiltration was increased by elevated $CO_2$ in the no-till treatment ($P = 0.010$) but not under conventional tillage ($P = 0.920$). Similarly, infiltration was higher under no-till than conventional tillage for plots exposed to elevated ($P = 0.006$) but not ambient ($P = 0.616$) $CO_2$.

Total sediment loss (lb $ac^{-1}$) was decreased by both elevated $CO_2$ ($P = 0.056$) and no-till management ($P = 0.030$). Again, there was a significant interaction between these two main effects treatments ($P = 0.057$). Sediment loss was decreased by elevated $CO_2$ under conventional tillage ($P = 0.020$) but not under no-till ($P = 0.989$), where these values were very low. Sediment loss was lower under no-till than conventional tillage for plots exposed to both elevated ($P = 0.076$) and ambient ($P = 0.011$) $CO_2$.

Total sediment C loss (lb C $ac^{-1}$) was lower under no-till, compared to conventional, tillage ($P < 0.001$). There a trend ($P = 0.133$) for sediment C loss to be lower under elevated, compared to ambient, $CO_2$. There was no significant interaction between these two main effects treatments ($P = 0.204$).

## CONCLUSIONS

1) Elevated $CO_2$ increased crop residue and water infiltration, decreased total sediment loss and tended to decrease sediment C loss.

2) No-till management increased crop residue, water infiltration, and decreased both total sediment and sediment C loss.

3) Interactions showed that elevated $CO_2$: increased residue in both tillage treatments, with the effect being greater under no-till; increased water infiltration only in the no-till treatment; and decreased sediment loss only under conventional tillage.

4) Interactions showed that no-till management: increased residue in both $CO_2$ treatments; increased water infiltration only in the elevated $CO_2$ treatment; and decreased sediment loss in both $CO_2$ treatments.

5) Overall, our findings indicate that both high $CO_2$ and no-tillage increased surface residues which could improve water infiltration and reduce soil loss.

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## REFERENCES

Amthor, J.S. 1995. Terrestrial higher-plant response to increasing atmospheric [$CO_2$] in relation to the global carbon cycle. Global Change Biol. 1:243-274.

Batchelor, J.A. Jr. 1984. Properties of Bin Soils at the National Tillage Machinery Laboratory, Publ. 218. USDA-ARS National Soil Dynamics Laboratory, Auburn, AL.

Keeling C.D. and T.P. Whorf. 2001. Atmospheric $CO_2$ records from sites in the SIO air sampling network. p. 14-21. *In* Trends: A Compendium of Data on Global Change. The Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN.

Kern, J.S., and M.G. Johnson. 1993. Conservation tillage impacts on national soil and atmospheric carbon levels. Soil Sci. Soc. Am. J. 57:200-210.

Littell, R.C., G.A. Milliken, W.W. Stroup, and R.D. Wolfinger. 1996. SAS System for Mixed Models. SAS Institute, Inc., Cary, NC.

Mitchell, R.J., G.B. Runion, S.A. Prior, H.H. Rogers, J.S. Amthor and F.P. Henning. 1995. The effects of atmospheric $CO_2$ on *Pinus palustris*: Nitrogen effects on foliar respiratory responses. J. Exp. Bot. 46:1561-1567.

Prior, S.A., G.B. Runion, H.A. Torbert, H.H. Rogers, and D.W. Reeves. 2005. Elevated atmospheric $CO_2$ effects on biomass production and soil carbon in conventional and conservation cropping systems. Global Change Biol. 11:657-665.

Rogers, H.H., W.W. Heck, and A.S. Heagle. 1983. A field technique for the study of plant responses to elevated carbon dioxide concentrations. Air Pollut. Contr. Assoc. J. 33:42-44.

Rogers, H.H., G.B. Runion, S.A. Prior, and H.A. Torbert. 1999. Response of plants to elevated atmospheric $CO_2$: Root growth, mineral nutrition, and soil carbon. pp. 215-244. *In* Y. Luo and H.A. Mooney (eds.) Carbon dioxide and environmental stress. Academic Press, San Diego, CA.

Sharpley, A.N., and P. Kleinman. 2003. Effect of rainfall simulator and plot scale on overland flow and phosphorus transport. J. Environ. Qual. 32:2172-2179.

Torbert H.A., S.A. Prior, H.H. Rogers, and C.W. Wood. 2000. Review of elevated atmospheric $CO_2$ effects on agro-ecosystems: Residue decomposition processes and soil carbon storage. Plant Soil 224:59-73.

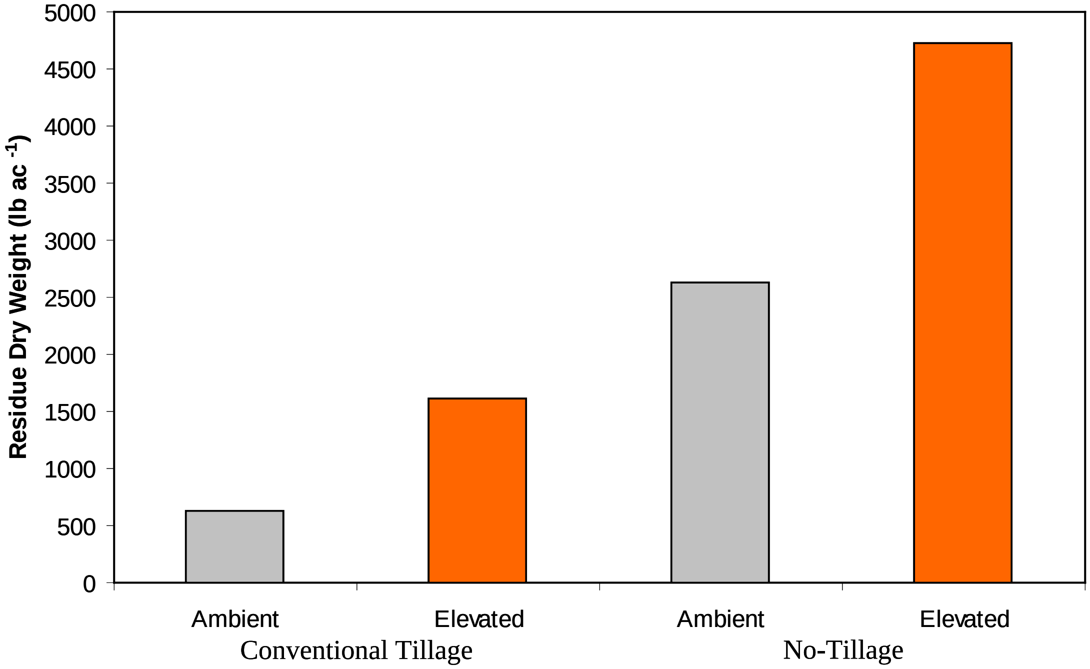

**Figure 1.** Residue dry weight under ambient and elevated atmospheric $CO_2$ conditions and two management systems (conventional tillage and no-tillage).

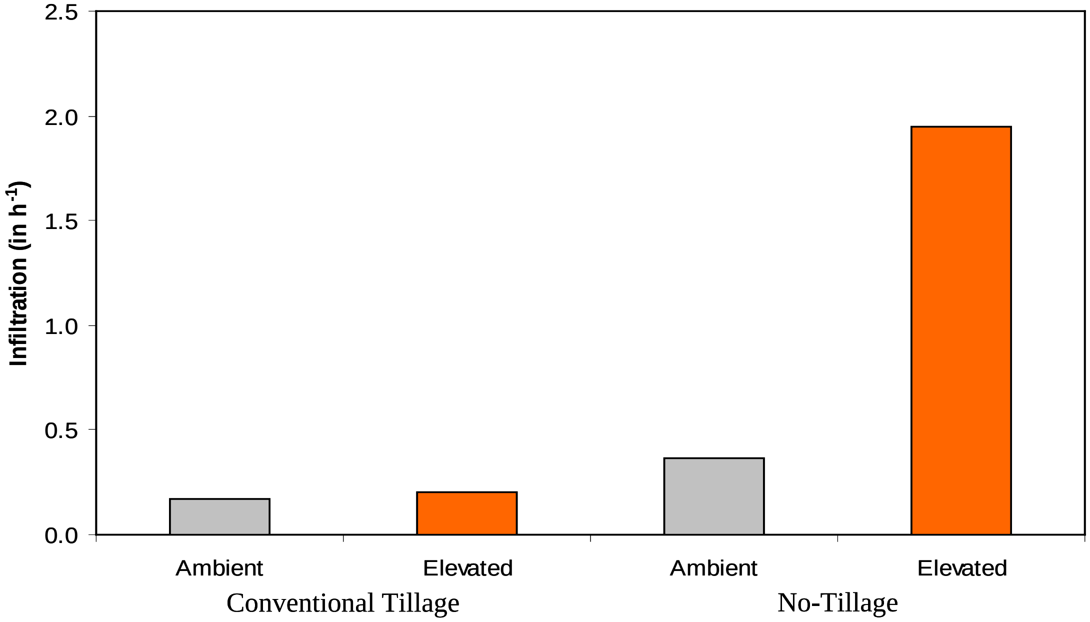

**Figure 2.** Water infiltration rate under ambient and elevated atmospheric $CO_2$ conditions and two management systems (conventional tillage and no-tillage).

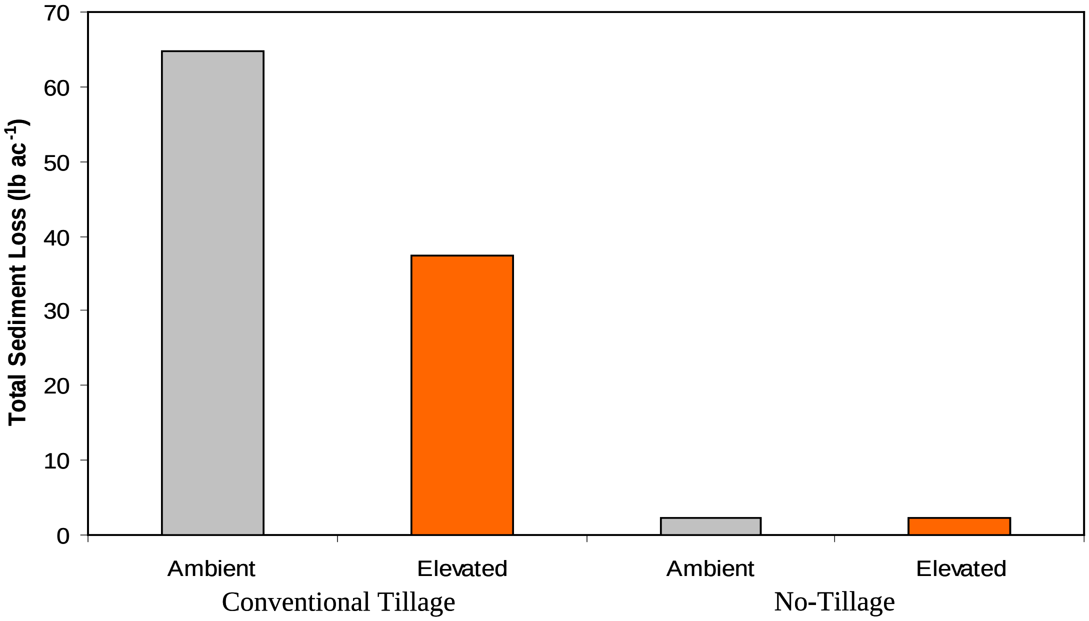

**Figure 3.** Total sediment loss under ambient and elevated atmospheric $CO_2$ conditions and two management systems (conventional tillage and no-tillage).

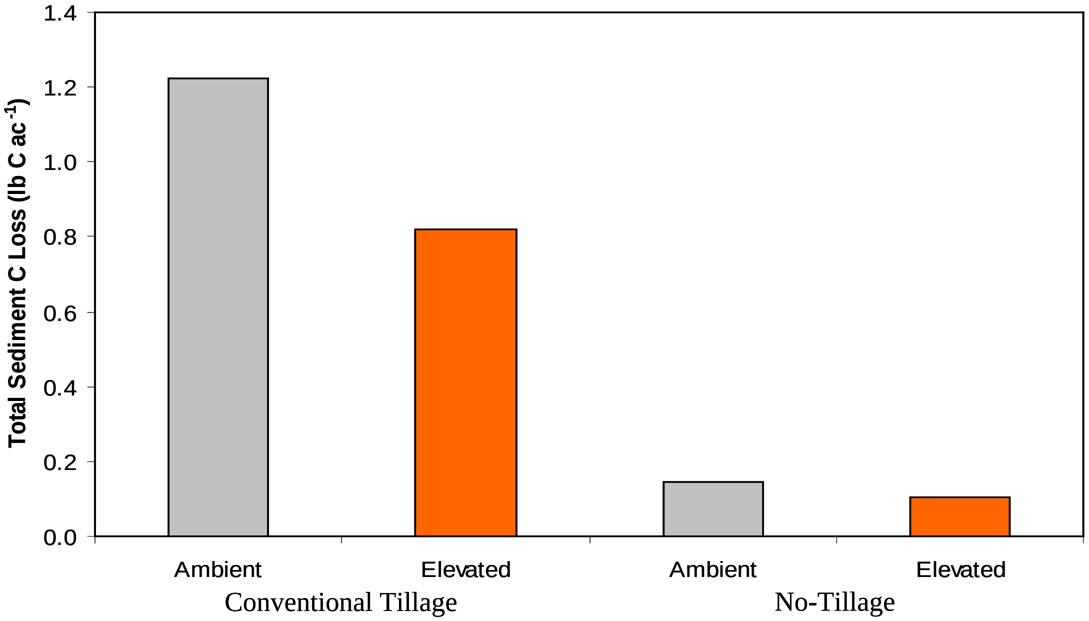

**Figure 4.** Total sediment C loss under ambient and elevated atmospheric $CO_2$ conditions and two management systems (conventional tillage and no-tillage).