Biofuel Cropping System Effects On Soil Moisture and Inorganic Nitrogen Leaching in Central Illinois

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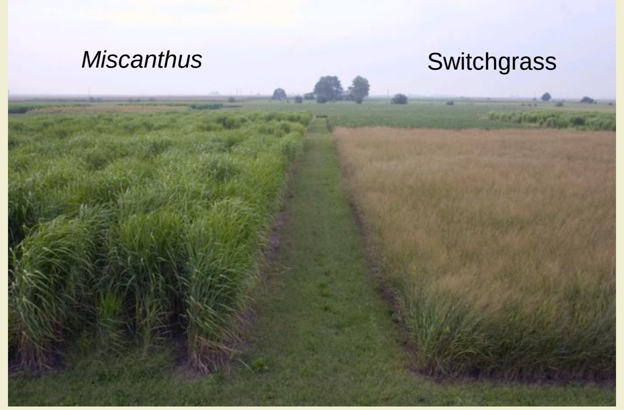
Introduction

Plants such as *Miscanthus x Giganteus* and switchgrass (*Panicum Virgatum, "Cave-In-Rock"*) have the potential to provide large amounts of biomass that could be used for energy and fiber products. However, little is known about the effects of growing *Miscanthus* on soil water and nitrogen fluxes. We grew both *Miscanthus* and switchgrass on tile drained silty-clay loam soils in east-central Illinois, comparing soil water content and nitrogen fluxes with conventionally grown corn and soybeans.



Research objectives: Evaluate soil moisture trends and nitrogen leaching in biomass (*Miscanthus* and switchgrass) crops compared to a conventional corn and soybean rotation.

Study Site

All field plots were located on the University of Illinois Crop Science Research and Education Center, approximately 5 km south of the main campus in Urbana (Latitude 88.23 W, Longitude 40.08 N). East-central Illinois has a warm, humid continental climate. Average annual temperature during 1971-2000 was 10.8 C, while the average annual precipitation was 1040 mm with approximately 6% occurring as snow. During 2005 through 2007 annual temperatures were 0.9 to 1.3 C above average, while in 2008 the average temperature as 0.3 C below the long-term average. During the study period, precipitation during the growing season was below the long-term average in 2005 and 2007, near average in 2006, and above average in 2008.

Soil Moisture

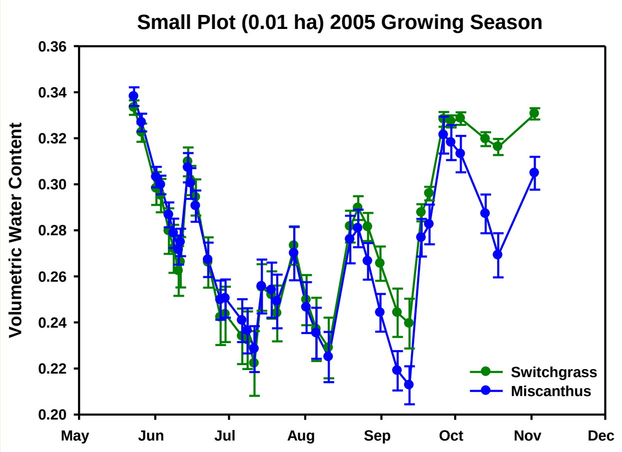
Soil water content was measured several times a week (from May to November) at 10-cm intervals to a depth of 90 cm using a Diviner 2000 from Sentek Sensor Technologies. This device uses frequency domain reflectometry to measure soil water content.

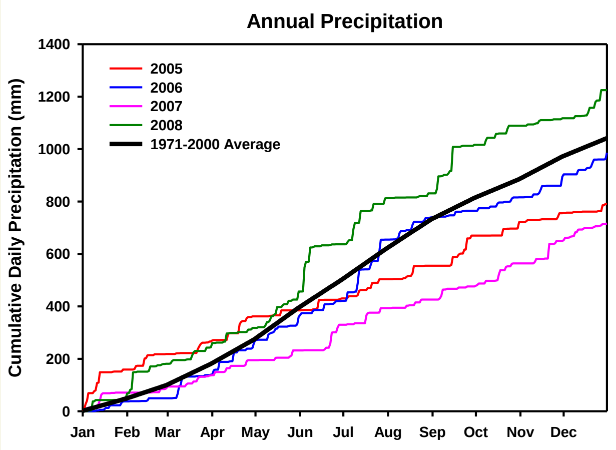
Initial comparisons of switchgrass and *Miscanthus* were conducted in four replicate small plots (0.01 ha) of each crop planted in May 2002. Soil moisture was measured in these plots starting in 2005 in order to obtain observations on mature stands.

Because small plots are subject to edge effects, larger (0.2 ha) plots were established to compare *Miscanthus*, switchgrass and corn-soybean. Four replicate large plots of switchgrass and soybean were established in 2004. An attempt to establish *Miscanthus* plots at the same time failed. In 2005, corn was planted in the 2004 soybean plots and soil moisture was initiated in the switchgrass and corn plots. Additionally, four 0.2 ha *Miscanthus* plots were planted and had successful establishment. In 2006, soybeans were planted into the 2005 corn plots, and soil moisture data collection in the large *Miscanthus* plots began. In 2007, corn was planted in the 2006 soybean plots and in 2008 the corn-soybean plots were split, with half planted to corn and half to soybeans. Each year, corn was fertilized with 202 kg N ha^{-1} at planting while other crops received no N fertilizer.

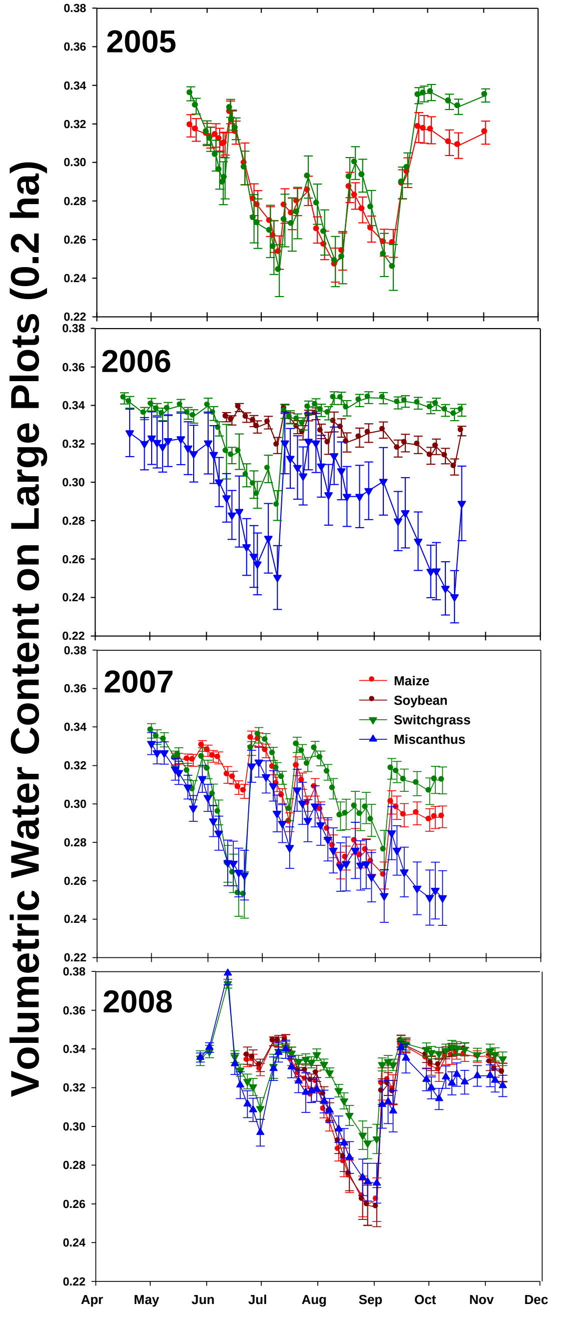
The largest difference we saw between the switchgrass and *Miscanthus* in the small plots was at the end of the growing season, where it appears the switchgrass stopped utilizing soil moisture before the *Miscanthus*. Subsequent years of small plot data mirror the data from the large plots. Each point on the following graphs represent a mean of 16 to 20 measurements and the error bars indicate the 95% confidence interval for each measurement date.

Most of the differences between switchgrass and *Miscanthus* occurred later in the growing season after switchgrass flowered (Sept) and began to senesce not needing water while *Miscanthus* continues transpiring into early November. The exception was in 2006 with a mild winter perennial grass growth began earlier and abundantly with switchgrass flowering in mid-Aug and *Miscanthus* growing well into October.





The corn-soybean system ended the growing seasons with significantly less soil moisture than switchgrass in three years (2005-2007 average difference of 21 mm), and significantly more soil moisture than *Miscanthus* in two years (2006-07 average of 48 mm). In 2008 the mean values were not statistically different ($p<0.05$). Early in the 2006-2008 growing seasons (prior to mid-July) soil moisture under the corn-soybean system was significantly greater than under either switchgrass (by an average of 31 mm) or *Miscanthus* (by an average of 40 mm). This was likely due to the earlier and more rapid growth of the perennial grasses early in the season compared to the annual crops. This was not observed in 2005, which was an unusually dry year and only the second growing season for switchgrass.



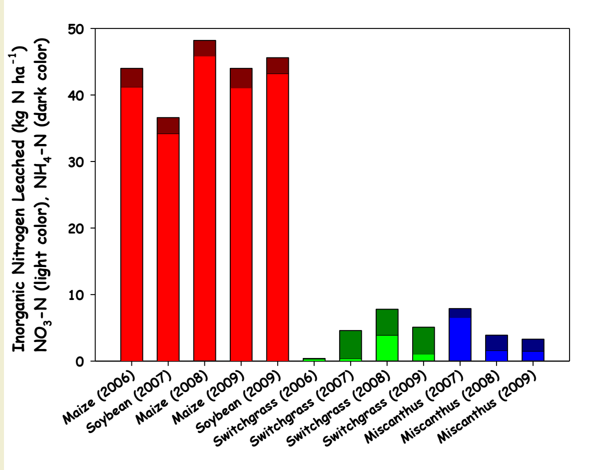
Inorganic Nitrogen Leaching

Inorganic N fluxes (nitrate and ammonium) were assessed using resin lysimeters buried at a depth of 50 centimeters below an undisturbed soil/plant profile. The resin used was Rexyn I-300.

Mean values of nitrate leached below 50 cm in the corn-soybean rotation ranged from 34.2 kg N ha^{-1} yr^{-1} in 2006 under soybeans to 45.9 in 2007 under corn. The mean for the 2006-2009 was 40.4 kg N ha^{-1} yr^{-1}. These means are statistically greater ($p<0.05$) than the nitrate flux values measured under switchgrass (ranging from 0.3 to 3.9) or *Miscanthus* (ranging from 1.5 to 6.6 kg N ha^{-1} yr^{-1}).

The 2006-2009 mean values of ammonium loss from switchgrass (4.0 kg N ha^{-1} yr^{-1}) was statistically greater ($p<0.05$) than ammonium losses from corn-soybean (2.4) or *Miscanthus* (1.8). Ammonium losses from the switchgrass were statistically greater than from *Miscanthus* in all years, while loss from switchgrass was statistically greater than from corn-soybean only in 2007-08. Additionally, the 2006-2009 mean ammonium losses from switchgrass were statistically greater than the nitrate losses from switchgrass. The causes for these differences are unknown, but may be due to a combination of factors. The magnitude of the ammonium leaching from switchgrass is relatively small and does not represent an agronomic or water quality concern.

Although there were greater ammonium losses from switchgrass, the 2006-09 mean total inorganic N (TIN) losses from switchgrass and *Miscanthus* were not statistically different, but were significantly less than TIN losses from corn-soybean.



Miscanthus field plot south of Champaign, IL in mid-August.

Conclusions

Our multi-year field observations demonstrated that *Miscanthus* significantly reduced soil moisture throughout much of the growing season compared to corn-soybean. Compared to corn-soybean, switchgrass reduced soil moisture early in the growing season, but later in the growing season soil moisture under switchgrass was frequently greater than from corn-soybean. Ion exchange resin lysimeters indicated that inorganic N leached below 50 cm from unfertilized switchgrass and *Miscanthus* was less than one seventh the magnitude of that leached from corn (fertilized with 202 kg N ha^{-1}) rotated with unfertilized soybean. Although unfertilized perennial biomass crops are likely to reduce nitrate movement to streams, they will also likely influence the hydrologic cycle, producing benefits (flood reduction) as well as costs (intensified and prolonged low flows). These effects need further research and consideration when designing policies and infrastructure for cellulosic biomass.

Acknowledgments

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