Impacts of Kentucky Bluegrass Invasion on Soil Hydrological Properties in the Northern Great Plains

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Kentucky bluegrass (Poa pratensis L.) is a non-native, cool-season (C_3), perennial grass that has become naturalized throughout the entire U.S. This species is an aggressive reproducer and produces abundant litter when not properly managed, which, in turn, creates a thick thatch layer of living and dead plant material between the soil surface and the plant canopy. This thatch layer has the potential to influence ecosystem services, including soil hydrological function, significantly by altering physical conditions at the soil surface.

Introduction

The grasslands of the northern Great Plains provide a wide array of services significant for many environmental, economic and ecological reasons. These ecosystems provide grazing rangeland for cattle by supplying a diverse mixture of nutritious native grasses and forbs throughout the growing season (Toledo et al., 2014).

They also provide habitat for threatened and endangered plant species (Cully et al., 2003), native birds, insects and small-mammal populations. All of these ecosystem services are possible as a result of the soils that support their function.

These important grassland ecosystems, and the functionality of their soils, have been threatened recently as environmental and anthropogenic shifts have caused fragmented and degraded fractions of land in their wake (Cully et al., 2003). One of the primary contributing factors in the deterioration of native prairie grassland is the rapid expansion of Kentucky bluegrass (*Poa pratensis* L.).

This invasive cool-season perennial species is an aggressive colonizer and an extremely successful reproducer. Its success is due, in part, to being able to take advantage of shifts in land management such as fire suppression, longer growing seasons and deferment (Printz and Hendrickson, 2015).

Kentucky bluegrass now dominates many grasslands in the Northern Great Plains and, consequently, reduces populations of native plant species (DeKeyser et al., 2009). This species also produces abundant litter, which paired with its characteristic shallow, dense rooting structure, creates a thick thatch layer between the soil surface and the plant canopy (Toledo et al., 2014).

This thatch layer can accumulate to the point that it affects the physical, mechanical and chemical conditions at the soil surface (Bosy and Reader, 1995). Through this process, Kentucky bluegrass has the potential to alter the ecological community structure and reduce vegetative biodiversity significantly, and potentially intercept rainfall from reaching the soil surface.

While the fact that Kentucky bluegrass affects certain ecosystem services is well-established, a principal knowledge gap still exists in understanding exactly how this litter layer affects the hydrological function of the soil (Toledo et al., 2014). Soil hydrological function is of key importance in these semiarid grassland ecosystems because rainfall and soil moisture often are the most limiting factors for vegetation growth (NRCS, 2017, Ecological Site Description), which, in turn, provides nutrition for grazing cattle and habitat for native fauna.

Cross section of Kentucky bluegrass thatch.

With the need identified to better understand the influence of Kentucky bluegrass on soil water, we conducted field experiments to assess the impact of Kentucky bluegrass dominance on soil water infiltration, runoff and the distribution of water in the soil profile.

Procedures

This study was conducted at the Central Grasslands Research Extension Center (CGREC) in south-central North Dakota during the fall of 2017. Eight sites distributed across the research center, all within the thin loamy Zahl-Williams-Zahill soil series complex, were selected. This soil type typically occurs on moderately sloped uplands and is moderately slow or slowly permeable, with low runoff, depending on the slope and the vegetative cover (Natural Resources Conservation Service Web Soil Survey, 2017). This is a common soil type in the area and was selected to be representative of the region as a whole.

Treatments (left to right)

1) Kentucky bluegrass + thatch

2) Kentucky bluegrass – thatch

3) burned

Half of the sites (n=4) were selected to represent Kentucky bluegrass-dominated vegetative communities. These sites historically had been excluded from grazing and burning, which resulted in the accumulation of a thick thatch layer. The other half of the sites (n=4) were in areas that had been burned in patches of 10 to 40 acres between April and May of 2017. These sites had a similar vegetative composition to the Kentucky bluegrass sites prior to burning, after which the fire disturbance resulted in a regeneration of predominantly native prairie grass and forb species. Each of these sites also was open to seasonlong, moderate grazing, which helped control litter.

At each site, we conducted field testing to measure the infiltrability of the soil. Two separate conditions were tested at each Kentucky bluegrass-dominated site: 1) undisturbed Kentucky bluegrass thatch conditions (KBG + Thatch), and 2) Kentucky bluegrass with above-ground vegetation and thatch manually removed to the mineral soil surface (KBG – Thatch).

Across four replicates of each of the three treatments, we used the Cornell Sprinkler Infiltrometer method to measure infiltration through ponded ring infiltration paired with simulated rainfall (Ogden et al., 1997). Following the experiment, we collected soil samples from depths of 0 to 5 centimeters (cm), 5 to 10 cm and 10 to 15 cm directly under the infiltrometer, and from an adjacent control site. These samples were measured for moisture content to determine the resulting distribution of water from the simulated rainfall event.

Results

Infiltration and Runoff

The difference between the simulated rainfall rate (r) and runoff rates (ro_t) was used to calculate the infiltration rate (i_t). Additional properties including sorptivity and field-saturated infiltrability were calculated to better characterize rainfall patterns in each treatment.

The estimation of sorptivity (S) is a hydraulic property describing early infiltration independent of rainfall rate, and the estimation of field-saturated infiltrability (i_{fs}) describes the steady-state infiltration capacity of the soil after an initial wetting period (Ogden et al., 1997). The adjustment factor used in the i_{fs} calculation is based on Reynolds and Elrick (1990) modeling.

KBG – Thatch treatments had the lowest overall rates of water runoff and highest infiltration, followed by KBG + Thatch (Figure 1). The burned treatment had the highest runoff and lowest infiltration.

Average sorptivity and field-saturated infiltrability followed a similar trend. Both parameters were highest in KBG – Thatch, followed by KBG + Thatch, and then burned treatments, with sorptivity values of 2.82, 1.74 and 1.40 cm/minute (min), and field-saturated infiltrability rates of 0.29, 0.17 and 0.10 cm/min, respectively (Table 1). No statistically significant differences for these parameters were detected across treatments using a paired t-test.

Soil Water Distribution

Burned sites retained the highest relative percentage of rainfall in the top 0 to 5 cm of soil out of all treatments (Figure 2). This treatment also had the greatest difference in percentage of rainfall retained between the 0 to 5 cm and 5 to 15 cm soil range. Both KBG + Thatch and KBG - Thatch treatments retained the majority of the rainfall water in the top 0 to 5 cm of soil as well. However, water distribution was more uniform with depth in these two treatments when compared with the burned treatment. KBG + Thatch retained more relative water than KBG – Thatch in the top 0 to 5 cm of soil. However, this pattern reverses in the 5 to 15 cm depths, with KBG – Thatch retaining more water than KBG + Thatch in these lower depths (Figure 2). We did not observe statistically significant differences for the distribution of water into the soil profile across treatment means.

Discussion

Soils that are dominated primarily by Kentucky bluegrass vegetation did not show any statistically significant changes in infiltration parameters after removing thatch (by hand or with fire) due to high variability within treatments. However, observed trends in infiltration parameters are supported by field observations of Kentucky bluegrass thatch and rooting characteristics.

An increase in infiltration with the manual removal of surface thatch may indicate that the thatch material can intercept water and impede infiltration. This idea additionally is supported by the observation that the KBG + Thatch retained more relative water in the top 5 cm of soil than the KBG – Thatch, which is opposite of the trend seen between these two treatments in the lower soil depths. These observations may indicate that the thatch layer is

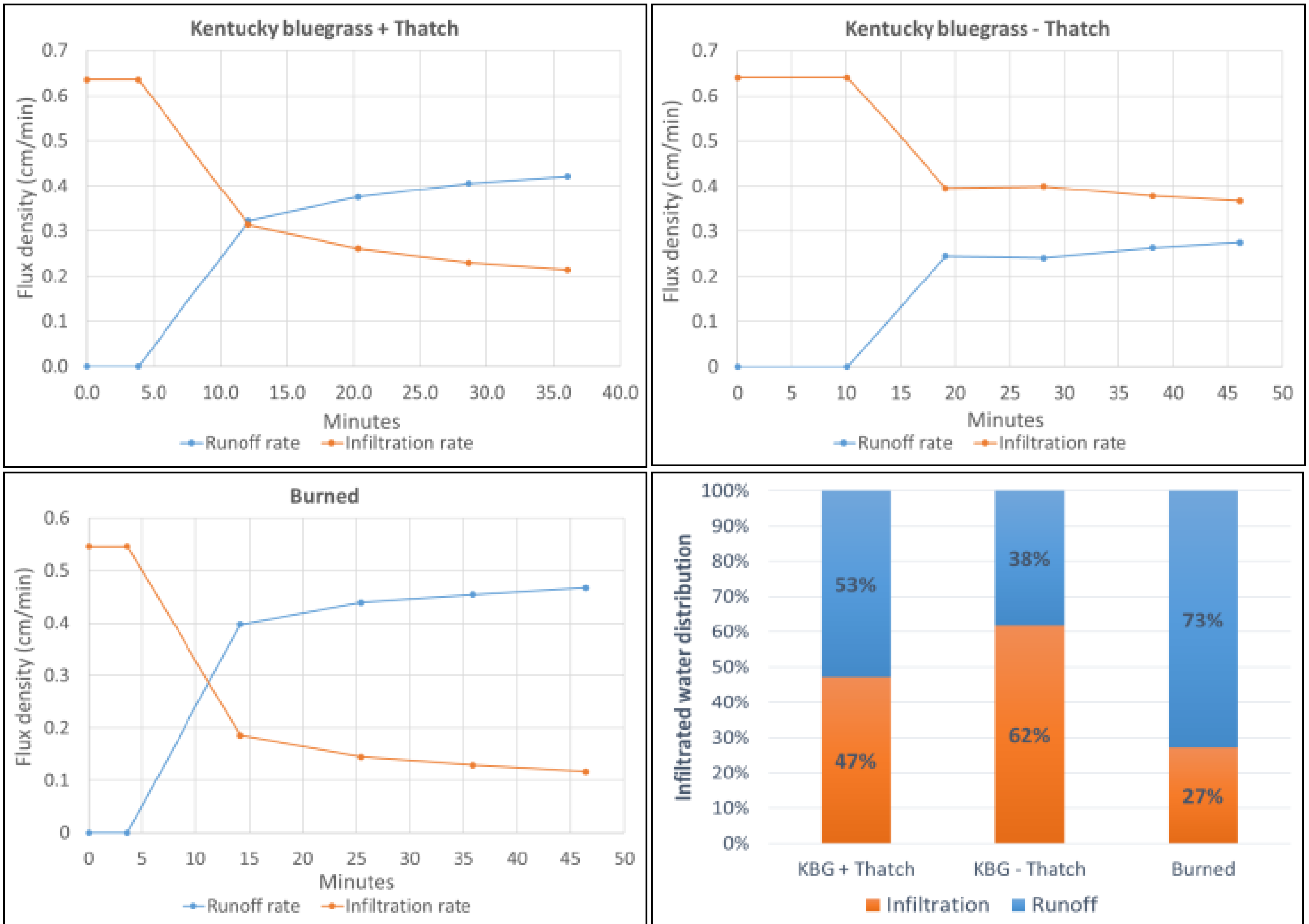

Figure 1. Average runoff and infiltration rates between treatments, and relative water budget (bottom right).

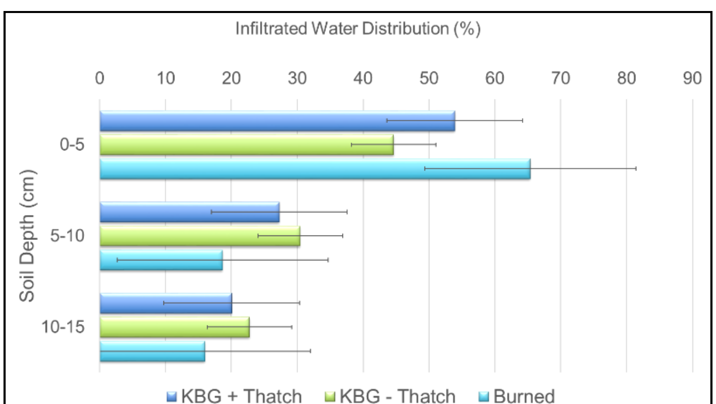

Figure 2. Percent of infiltrated water (by mass) within the top 15 cm of the soil profile.

Treatment	Sorptivity (cm/min)	Field-Sat Infiltrability (cm/min)
KBG + Thatch	1.74	0.17
KBG - Thatch	2.82	0.29
Burned	1.40	0.10

Table 1. Average sorptivity and field-saturated infiltrability rates.

retaining rainfall water and preventing it from reaching lower soil depths.

The decrease in infiltration in the burned treatment may be explained by the shift in vegetation from Kentucky bluegrass to native grass and forb species following a fire disturbance. Kentucky bluegrass produces a thick layer of dense, shallow roots, which are presumed to promote water flow and conductivity at the surface and deeper into the soil profile.

Immediately following a burning event, the above-ground vegetation and rooting structures die, and pores may collapse as sparse native species re-establish. The change in soil surface condition and porosity may result in reduced infiltration after fire.

With time, this pattern may become less pronounced as native species colonize and generate more roots deeper into the soil profile.

Directions for research in 2018 include:

- Examination of soil structure (pore distribution) under Kentucky bluegrass before and after fire
- Continued infiltration testing to observe differences in burned treatments as sites recover from the disturbance
- Characterizing the differences between treatments in soil moisture and temperature in the top 15 cm of soil through in-situ stations and sensors

Conclusion

The preliminary results from this study indicate that Kentucky bluegrass dominance and land management practices may play a role in soil water infiltration. Soil water infiltration, in turn, affects plant growth and, thus, nutritional value for grazing livestock. Future research will help provide important characterization of soil properties, water dynamics and the rebounding nature of these grassland ecosystems following a fire disturbance.

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