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Surface Albedo and Soil Heat Flux Changes Following Drilling Mud Application on Mixed-grass Prairie

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Background and objectives

Drilling mud systems are used by the petroleum industry to facilitate and expedite the drilling of oil and natural gas wells. Waste drilling mud and drill cuttings must be properly disposed to avoid adverse environmental effects. In western Canada, landspraying while drilling (LWD) is an approved disposal method for water-based muds (freshwater gel) and involves spraying the mud on cultivated or uncultivated land at controlled, low application rates during the drilling process. Provincial regulations require that LWD should be targeted for cultivated land first, then tame hay land, and finally native prairie as a last resort where allowed (Alberta Energy and Utilities Board, 1996).

Since drilling mud applied on native prairie is not incorporated into the soil, the resulting ground surface modifications (including color and moisture effects) may alter the surface albedo (α) and soil heat flux (G), hence temperature regime of the soil. Soil temperature influences, inter alia, seed germination, plant emergence, root growth, nutrient uptake, plant development, and microbial activity (including organic matter decomposition) in soils, and therefore, has an important effect on native rangeland health and productivity. Soil heat flux is also an important component of models for estimating surface energy balance and evapotranspiration.

In this poster, we report on the changes in α, G, and temperature of the soil during the first 40 d following application of a water-based drilling mud system consisting of freshwater, bentonite (gel), and as-needed non-toxic additives to enhance mud performance. This was part of a larger study examining the effects of LWD on native vegetation and soil properties.

Experiment details

- **Location:** Canadian Forces Base Suffield, Alberta, Canada
- **Ecosystem:** semi-arid, mixed-grass native prairie (*Bouteloua gracilis* – *Stipa comata* community)
- **Soil:** Brown Chernozem (Typic Haploboroll; sandy loam)
- Plot size: 5 m x 4 m
- **Treatments:** Drilling mud rates: 0, 40 (max. allowed during summer), and 80 $m^3\ ha^{-1}$
  - one-time application using 9-L watering cans (Fig. 1)
- **Drilling mud system:** freshwater gel (bentonite); s.g. 1.13 $g\ cm^{-3}$
- **Monitoring period:** 42 d [day of year (DOY) 180 (Jun 29) – DOY 122 (Aug 10)]

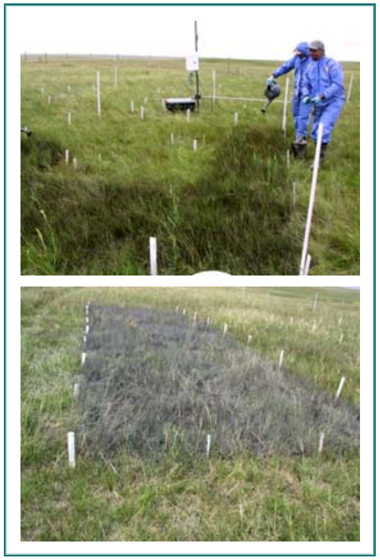

Figure 1. Top: drilling mud application using watering cans; below: plot after mud application.

Measurements

- Incoming solar radiation (R_{is}) measured using a Li-Cor LI-200SA pyranometer (Campbell Scientific, Inc., Logan, UT)
- Surface albedo measured between 11:00 am and 2:00 pm on 5 cloudless days using inverted and upright Li-Cor LI-200SA pyranometers (one pair available, therefore measurements taken in random rotation of the plots)
  - sensors positioned 0.6 m above ground using 3-m long aluminum rod
- Soil heat flux (G) measured at the 5-cm depth using soil heat flux plates (Thornthwaite model 610, Elmer, NJ)
- Soil temperature measured with two copper-constantan thermocouples at the 2.5-cm depth
- Volumetric soil moisture content in the 0- to 5-cm depth measured using Theta probe soil moisture sensors (type ML2X, Delta-T Devices, Cambridge, UK) based on time domain reflectometry (TDR)
- All above measurements taken at 5-s intervals and 5-min averages recorded by a datalogger (CR21X, Campbell Scientific Inc., Logan, UT)

Results

- Daily mean R_{is} ranged from 210 to 340 W m^{-2} while daily maximum R_{is} ranged from 830 to 1090 W m^{-2} (Fig. 2).
- Surface albedo (α) differed significantly among the LWD rates (Fig. 3) and was highest with the zero control (mean 0.218) followed by the 40 $m^3\ ha^{-1}$ rate (0.185), while the 80 $m^3\ ha^{-1}$ rate had the lowest α of 0.179. However, differences between the control and treated plots decreased with time (days after treatment).
- Daily mean soil temperatures in the 0- to 5-cm depth (Fig. 4) increased significantly ($P < 0.0001$) with mud application, with overall means of 21.7, 23.2, and 23.8°C, respectively, for the 0, 40, and 80 $m^3\ ha^{-1}$ rates across the sampling period. The difference between the two latter rates, however, diminished with time and was non-significant after DOY 200 (20 d after mud application).
- Consistent with the observed temperature effects, G increased ($P < 0.0001$) with increasing drilling mud rate (Fig. 5) and averaged 2.32, 4.49, and 6.40 W m^{-2} for the 0, 40, and 80 $m^3\ ha^{-1}$ rates, respectively. Daily maximum G was highest at the 80 $m^3\ ha^{-1}$ rate throughout the sampling period (mean 55.8 W m^{-2}) but did not differ significantly between the control (44.3 W m^{-2}) and 40 $m^3\ ha^{-1}$ (38.7 W m^{-2}) treatments.

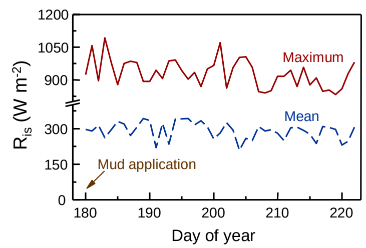

Figure 2. Temporal variation in daily mean and maximum incoming solar radiation (R_{is}) during the study.

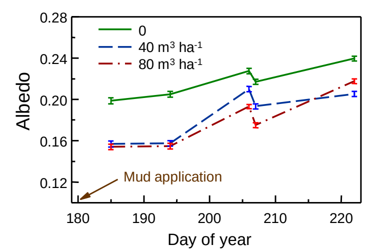

Figure 3. Drilling mud rate effects on ground surface albedo measured between 11:00 am and 2:00 pm.

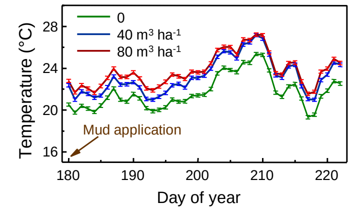

Figure 4. Drilling mud rate effects on soil temperature in the 0- to 5-cm depth.

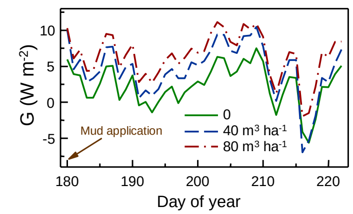

Figure 5. Drilling mud effects on soil heat flux density (G) at the 5-cm depth.

Conclusions

Drilling mud application at rates investigated in this experiment increased soil heat flux at the 5-cm depth by, on average, up to 176%. This in turn was associated with a significant increase in soil temperature in the 0- to 5-cm depth. These effects may be related in part to the observed decrease (up to 18%) in the surface albedo (DOY 180-222) with mud application. By modifying heat flow and temperature in the root zone, drilling mud application may have important effects on processes such as seed germination, root growth, nutrient uptake, plant development, and microbial activity, with important implications on overall biomass production in this fragile ecosystem.

Reference

Alberta Energy and Utilities Board. 1996. Directive 50: Drilling Waste Management. Alberta Energy and Utilities Board, Calgary, AB. 143 pp.

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