A Water-Energy Balance Approach to Quantify Winter Runoff from Dairy Agroecosystems

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Objectives

Year-round land applications of manure are logistical reality for many dairy farms, but may accelerate nutrient losses because of the reduced infiltration potential of frozen soils, magnitude of melt events, and thermal properties of manure. **Our goal is to improve the understanding of the physical processes controlling soil frost development, snowmelt infiltration versus runoff, and nutrient losses from the winter manure applications.**

Our supporting objectives quantifya coupled water-energy balance to:

1) identify the mechanisms that control the infiltration of frozen soils, hence nutrient losses in runoff, and
2) link changes in snowmelt rates to differences in tillage and the timing of manure applications on frozen soils.

Expected & Preliminary Results

Expected Results for Winters 2015-16, 16-17, 17-18

Tillage: The rough surface of soils under conventional tillage will retard runoff, allowing for greater infiltration during the freezing season, hence less cumulative runoff, relative to soils under no tillage.

Manure: Greater infiltration is expected from the late-fall versus mid-winter applications. Proposed mechanisms include the extent of frost development and the energy available for snowmelt from the surface albedo.

Preliminary Results from Winter 2014-15 Pilot Study

Snow dampened ground heat fluxes, which were significant during and after thaw. Soil moisture approximates the degree of frost formation and must be substantiated through the soil freezing characteristic curve (Fig. 3).

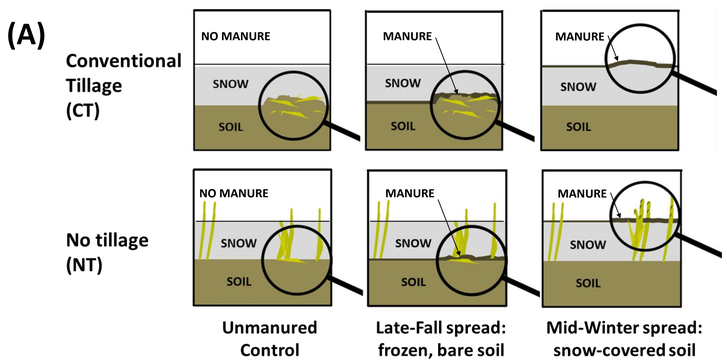
Methods

Location: A south-facing, continuous corn-for-silage field with 6% slope at Arlington Research Station in WI (43°18' N, 89°20' W)

Treatments: 18 plots (each 5 x 15 m) in a 2x3 complete factorial design in triplicate test tillage and the timing of liquid manure applications (65.4 kL ha^{-1}) on nutrient losses (Fig. 1)

Timeline: Winter 2014-15: pilot year to test instrumentation
Winters 2015-16, 16-17, 17-18: full study with 18 plots

Instrumentation: Measurements include soil parameters to depths of 1.30 m, hydrological and atmospheric conditions (Fig. 2)



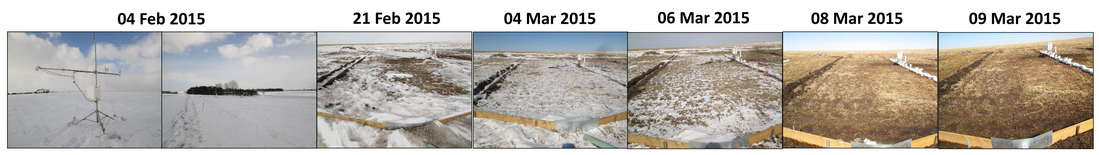


Figure 1. A) Six treatments test tillage and the timing of manure applications on nutrient loss during frozen conditions. Conventional vs. no tillage tests rough vs. smooth soil surfaces while the timing of applications tests the interaction of manure with snow, infiltration, and melt energy. B) Complex soil surfaces (*e.g.* albedo) in chronological sequence during late winter 2014-15 highlight the value of direct field data.

The Water-Energy Balance

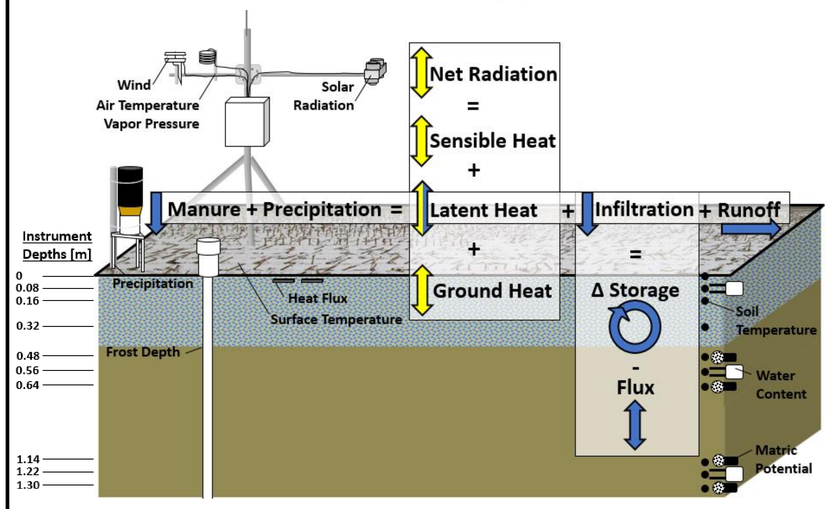


Figure 2. Schematic of the measured soil, hydrological, and atmospheric parameters, which allow for the quantification of infiltration capacity, runoff, and energy available for melt. Not pictured: passive, divider runoff collection with Arduinos and snow depth instruments.

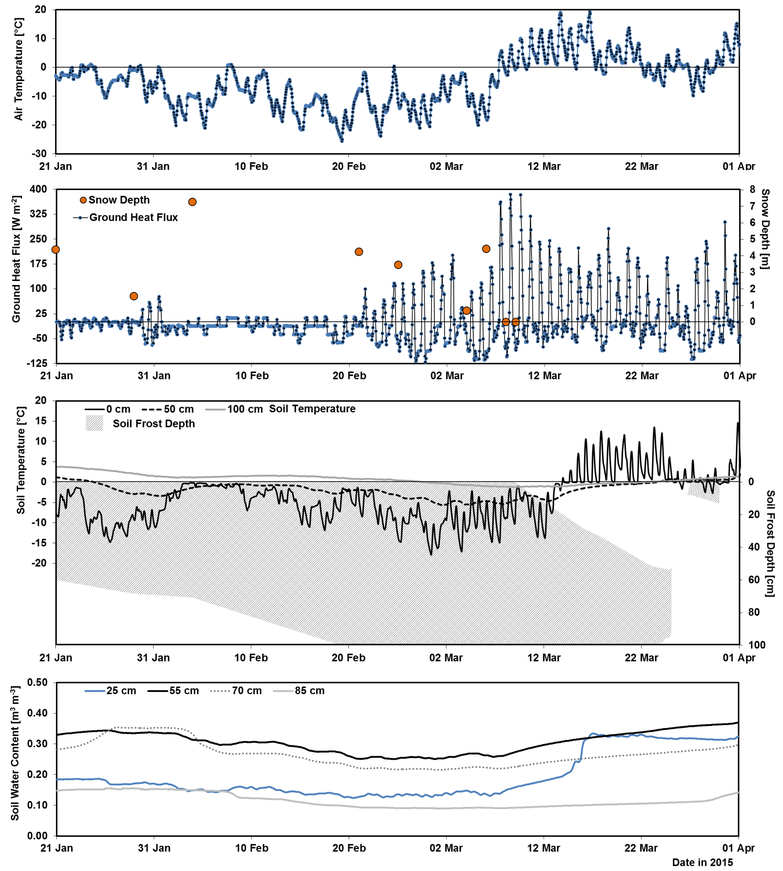


Figure 3. A sample of the key parameters for the water-energy balance, measured in the absence of manure during late winter 2014-15. Data were collected hourly, with the exception of soil frost and snow depths, which were collected daily to weekly.

Take-Home Message

The importance of this mechanistic field study is highlighted by concern for nutrient losses during melt events and the relative dearth of existing wintertime field data. Because of the complexities of frozen soil processes, snowpack dynamics, and the liquid manure matrix, evaluating manure management during the freezing season requires a comprehensive field study with soil, hydrological, and atmospheric measurements. From the water-energy balance approach, conventional tillage is expected to promote infiltration relative to no tillage and less runoff is expected from soils with early applications of manure relative to those with mid-winter applications. Results will ultimately inform manure management models (SurPhos) and regulations in Wisconsin (NRCS 590).

Acknowledgements

We thank Peter Wakeman, Zach Zopp, Nick Bero, Jim Richmond, Matt Massman, and Donale Richards for their tireless field assistance, Dr. Bill Bland for his technical feedback, and the Arlington Research Station (University of Wisconsin) for their collaboration.

This project is supported by the USDA-NIFA-AFRI (#3958); G.A. Harris Fellowship (Decagon Devices, Inc.); NCR-SARE Graduate Student Grant; and William T. Dible Terra International, Inc. Scholarship, Richard D. Powell Memorial Scholarship, and Ruth & Carl Miller Academic Merit Award (College of Agriculture and Life Sciences, University of Wisconsin-Madison).