Understanding Soil Frost and Snow Depth Dynamics at Kingman Farm

Zoe Wegrzyn[1], Zachary Holt[1], David Testerman[2], Andrew Irwin[1], Isabella Falcone[1], Jeremy Johnston[3], Mahsa Moradi[3], and Jennifer Jacobs[1,3]

[1]University of New Hampshire College of Engineering and Physical Sciences, [2]University of New Hampshire College of Life Science and Agriculture, and [3]University of New Hampshire Earth Systems Research Center, Institute for Study of Earth, Oceans, and Space.

Why is Soil Frost Important?

- Soil frost and snow variability are critical to climate, hydrologic, and agricultural systems.
- Reliance on air temperature oversimplifies frozen ground dynamics.
- We hypothesize that soil frost variability is driven by factors that include snow depth, solar radiation, and hydraulic conductivity.
- Our data sources include time-series field measurements, LiDAR-derived canopy cover, and soil type maps.
- Our objective is to advance understanding and modeling of frozen ground processes.

Motivations and Research Questions

We collected soil frost and snow depth data from 11 frost tubes at Kingman Farm and observed notable site-specific differences., mostly consisting to variation in soil frost depth. Site KF-FF-4, located in a swampy area, consistently showed low frost despite deep snow, while site KF-CH-2, in an exposed field, remained melted out, suggesting influences from soil moisture and solar exposure. This led us to develop our research questions:

- What determines the variability in soil frost?
- How are the variables that impact frost levels connected? Are some more significant than others?

Conclusions and Next Steps

There appears to be a link between snow depth and frost variation, which may be due to the insulating effect of snow. Further research is needed to isolate the effects of snow depth on frost. We hope to further study the correlation between soil frost, soil type, and hydraulic conductance to find a relationship. During the analysis phase we used raster maps of soil and landcover attempt to find relationships. We hope to expand upon our findings in the next phase of this project.

Site Description and Sampling Methods

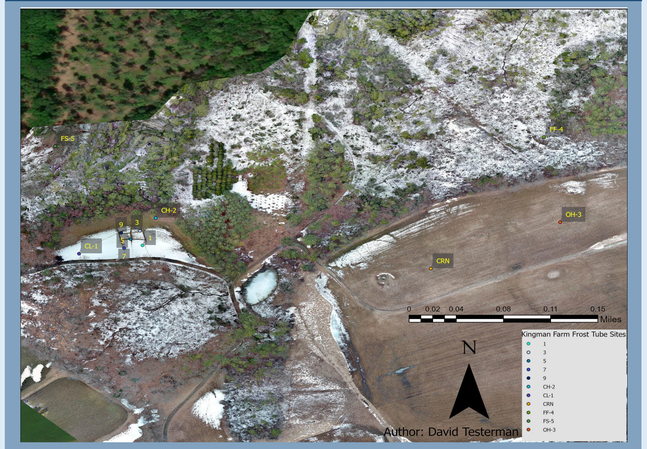

Figure 1. An arial image of Kingman farm taken by drone showing the farm during the snowmelt. This image specifically highlights the areas of shade in comparison to areas of sun based upon presence or absence of snow.

a) b) c)

Figure 2. Images of an undergraduate student taking snow (b) and frost samples (c) at a frost tube after a snowstorm. Sampling was preformed 2-3 times a week during the 2024-2025 winter. (a) is a labeled diagram of the frost tubes that we used, and the measurements that were taken.

Site ID	Land Cover	Normalized Canopy Cover	Canopy Height (m)	Solar Exposure (Percentage)	Mean Frost Depth (cm)	Mean Snow Depth (cm)
KF-1	Closed field	0.42	0.1	12.06	15.44	18.01
KF-3	Closed field	0	0.1	32.19	11.96	15.31
KF-9	Closed field	0.48	0.1	29.31	17.22	16.19
KF-5	Closed field	0.23	0.1	18.31	19.29	14.79
KF-7	Closed field	0.2	0.1	5.94	13.83	15.5
KF-CL-1	Closed field	0.12	0.2	7.13	12.03	18.7
KF-CH-2	Closed field	0.53	13	41.81	8.77	3.9
KF-OH-3	Open field	0.44	0.1	59	15.55	11
KF-FF-4	Deciduous forest	0.98	13.4	5.19	5.1	16.3
KF-FS-5	Mixed forest	1	25.9	2.63	6.65	8.8
KF-CRN	Open field	0.56	0.2	49.56	15.55	10.6

Figure 3. This table summarizes multiple metrics of importance for the data collection season at the site.

Experimental Design

- We collected 40-43 frost and snow samples per site from Dec 31st to March 19th. From this set, 11 frost depth measurements were erroneous and were interpolated.
- Further analysis was conducted on soil types and hydraulic conductance using raster set from the POLARIS data set.

Preliminary Results and Discussion

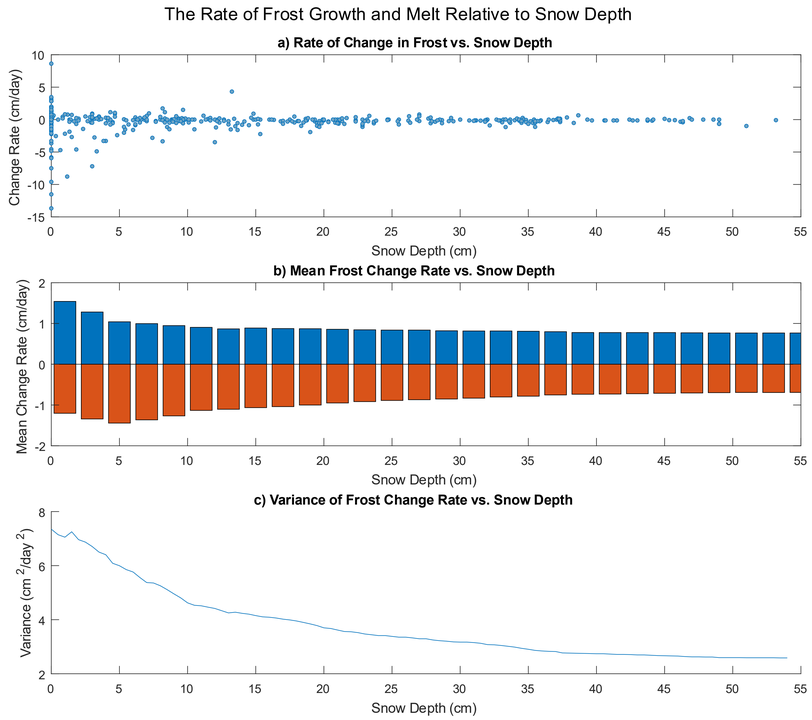

Figure 4. Here, the rate of change of frost depth is examined to determine the amount of growth or meltage over the sampling interval. In **a)**, the rate of change is compared across snow depth. The values in the scatter plot are averaged over 2 cm snow depth intervals in **b)**. Note the amount of frost change is greater at lower snow depths. This is shown in **c)**, where the variance of the frost change is calculated and plotted. The variance is higher at lower snow depths, and decreases at higher snow depths. This may be explained by the insulating effects of snow, but there are likely other factors involved (such as temperature and other environmental conditions).

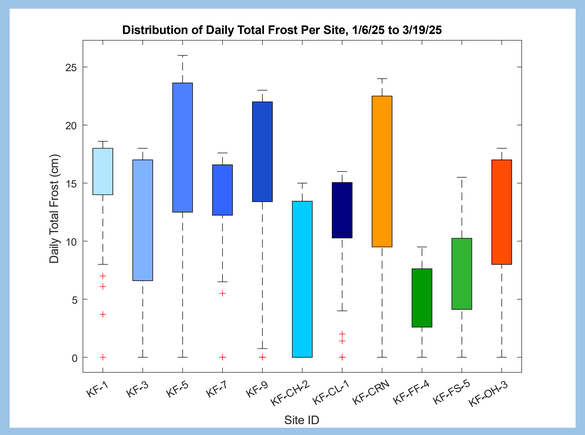

Figure 5. A box plot showing the distribution of "total frost" amounts sampled throughout the season. "Total frost" is a measure of the total amount of frost in the ground.

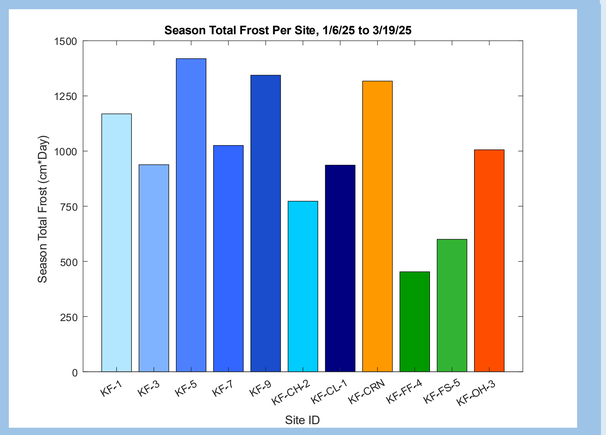

Figure 6. To assess each site over the season, a new summary statistic was created. "Season Total Frost" integrates the total amount of frost at each site over the duration of time that frost remained in the ground.

Characterizing the 2025 Winter

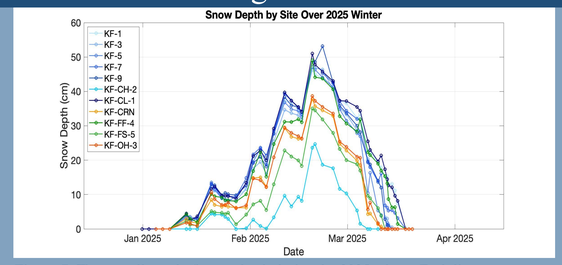

Figure 7. The overall trend of snow depth during the 2025 winter. Each line represents a different site, with shades of blue representing sites located in a closed, sheltered field, shades of orange representing sites located in a large, exposed field, and shades of green representing forested sites.

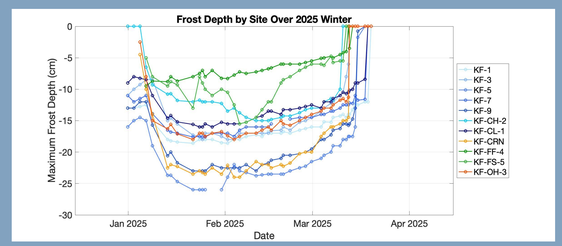

Figure 8. The overall trend of maximum frost depth during the 2025 winter. This plot uses the same color scheme as Figure 7. Frost varies by environment due to factors, including canopy, and this is evident in forested sites having shallower frost.

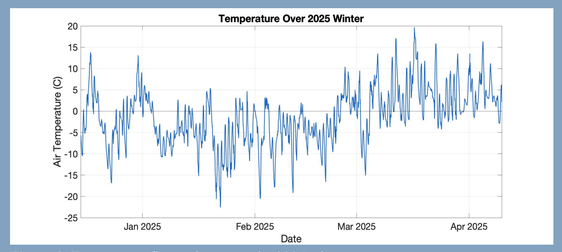

Figure 9. Temperature fluctuations over the 2025 winter season.

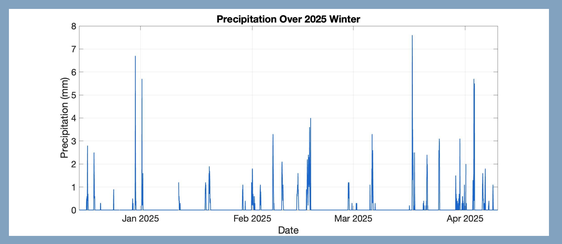

Figure 10. Precipitation by day over the 2025 winter season.

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References

Chaney, N. W., Minasny, B., Herman, J. D., Nauman, T. W., Brungard, C., Morgan, C. L. S., et al. (2019). POLARIS soil properties: 30-m probabilistic maps of soil properties over the contiguous United States. Water Resources Research, 55, 2916–2938.