College of Arts and Sciences, Atmospheric Sciences Program

Impact of Landscape on Soil Conditions in Central Ohio

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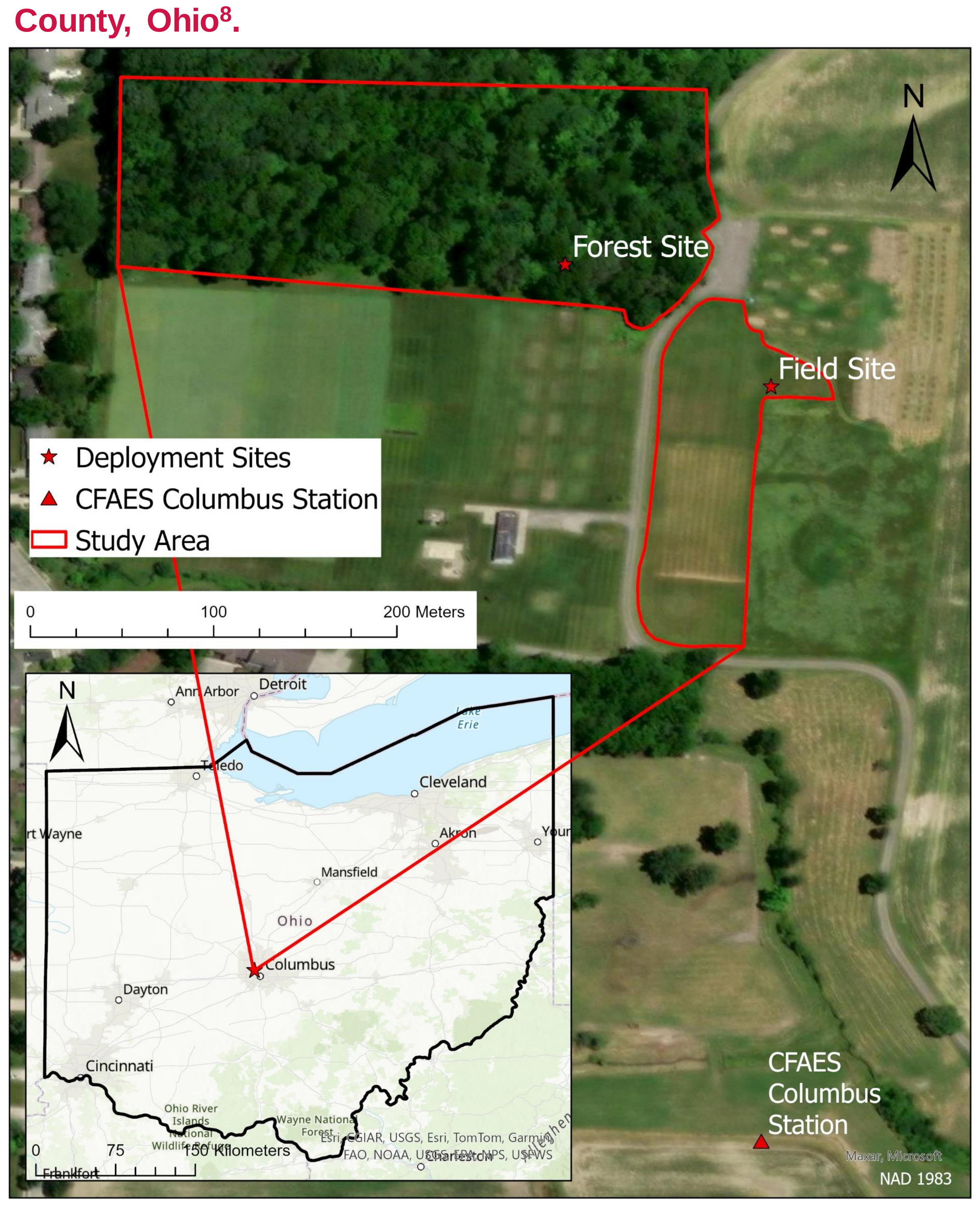
INTRODUCTION

Soil variables and composition can regulate the ground heat flux, or how much heat is released or absorbed by the soil[9]. This makes soil an essential variable in the analysis of microclimates. Different landscapes will impact a specific soil type's characteristic and how effective it may be in retaining moisture or maintaining heat which then impacts greater atmospheric conditions in the environment[1]. While previous research has focused on analyzing the chemical composition of soil[5] and individual soil variables such as moisture[7], we focus on how different landscapes impact the soil's behavior in connection to variables regulating the ground heat flux, particularly soil temperature and soil moisture.

Figure 1, Deployment sites and greater context in Franklin County, Ohio[8].



The locations in this study are two sites located at Waterman Farm in Columbus, Ohio. The sites are each representative of a portion of the greater red-bounded areas. Marked south of the study area is the CFAES Columbus Station[2] from which overlying weather data was collected for the study period. The underlying basemap for Ohio is ESRI's World Topographic Basemap, v2[4]. The underlying basemap for the sites is ESRI's World Imagery Basemap[3].

AIM

This study's aim is to analyze the impact that variations in soil conditions across different landscape settings have on the relationship between soil moisture, soil temperature, and the ground heat flux. This analysis is conducted across two sites with differing landscapes, one in a deciduous forest and one in an open field (Fig. 1) to achieve that goal.

METHODS

We deployed several instruments in an open field and in a forest, both located within the Waterman Farm property in Columbus, Ohio. We chose locations based on representativeness of central Ohio, accessibility, and proximity between the two landscape types. At both sites, these instruments collected the average, maximum, and minimum of the allocated variables:

- **HFP01 sensor** – ground heat flux (W/m^2)
- **CS616** – volumetric water content (VWC)
- **109 probe** – soil temperature (ºC)
- **CR1000 datalogger** – data collector

The datalogger collected measurements every 5 minutes and output data every 3 hours for 2 weeks, from October 6th, 2023, to October 21st, 2023. We accessed The Ohio State University CFAES Weather System (Fig. 1) to find a relationship between soil variables and external atmospheric conditions when there was a dramatic change in the data collected.

We used Python and the SciPy, NumPy, and MatPlotLib packages for data analysis and graphing.

ArcGIS Pro was used to create a map of the sites.

Table 1, Calculated statistics for each variable at the field and forest sites.

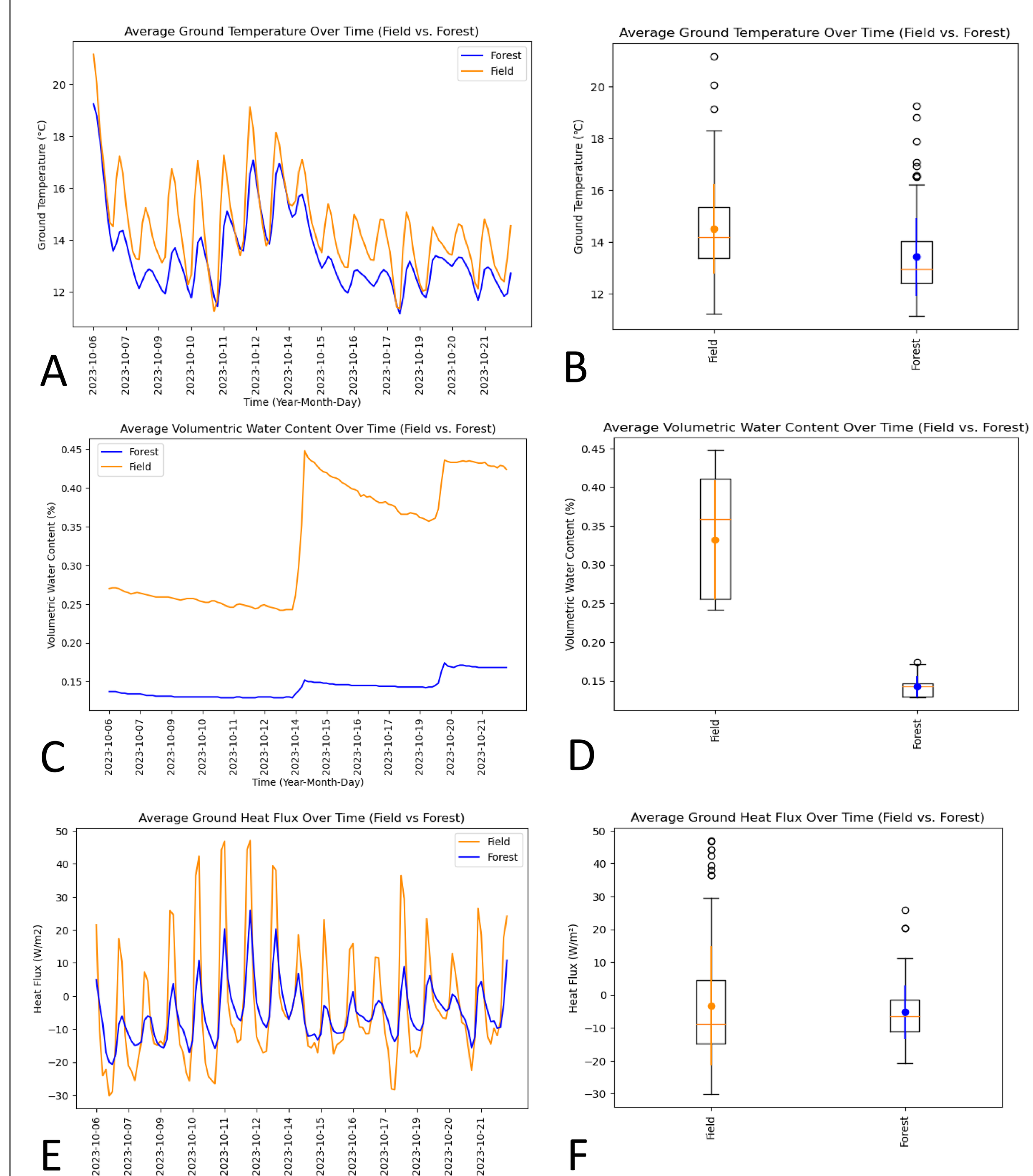
A	Average (°C)	Median (°C)	Range (°C)	Pearson Correlation
Field Temperature	14.51	14.19	9.92	0.881
Forest Temperature	13.43	12.97	8.09	0.881

B	Average	Median	Range	Pearson Correlation
Field VWC	0.33	0.36	0.206	0.897
Forest VWC	0.14	0.14	0.045	0.897

C	Average (W/m²)	Median (W/m²)	Range (W/m²)	Pearson Correlation
Field Ground Heat Flux	-3.34	-8.88	77.14	0.845
Forest Ground Heat Flux	-5.24	-6.52	46.57	0.845

Average, median, and range were calculated for the soil temperature (A), volumetric water content (B) and ground heat flux (C) at each site. Pearson Correlations were also calculated between sites for each individual variable.

Figure 2, Time series and box-and-whisker plot comparison of each variable between the field and forest sites.



Timeseries graphs for average ground temperature (A), average volumetric water content (C), and average ground heat flux (E) are displayed next to the box-and-whisker plot for the corresponding variable: ground temperature (B), volumetric water content (D), and ground heat flux (F).

RESULTS

Average soil temperature measured at the two sites was generally higher in the field, and the diurnal maximum and minimum values occur slightly before those in the forest (Fig. 2A). This trend is due to more direct solar radiation causing more surface heating of the field soil.

VWC in the field was also consistently higher than in the forest, and responded much more dramatically to precipitation events, on October 14th (1.6 cm) and October 19th-20th (1.4422 cm) (Fig. 2C). Precipitation likely was deflected by debris or foliage in the case of the forest, allowing for less water to reach the ground. Additionally, higher soil temperatures allow for greater volumes of water to be held[6] which is reflected by the temperature and VWC data.

$$Q_G = -k_{HS} \cdot C_s \cdot \frac{\Delta T}{\Delta z} \qquad (1)$$

The magnitude of the ground heat flux was larger in the field than in the forest (Fig. 2E). This could be caused by both decreased incoming radiation due to landscape influences including tree cover and influences from the VWC and temperature. The ground heat flux equation (1) indicates that higher levels of water content lead to increased ground heat flux because of the properties of thermal conductivity, heat capacity, and thermal admittance. Additional analysis is needed to determine the extent that each of these variables impacts heat flux values.

CONCLUSIONS

Results show that landscape conditions influence ground heat flux both directly and by affecting variables such as soil temperature and volumetric water content that determine the magnitude of the ground heat flux. The forest site experienced smaller heat fluxes consistently over the two-week study period in comparison to the field. These relationships are important because ground heat flux is a determining factor in the surface energy balance.

BIBLIOGRAPHY

1. Al-Kaisi, M. M., L. Rattan, K. R. Olson, and B. Lowery, 2017: Fundamentals and Functions of Soil Environment, *Soil Health and Intensification of Agroecosystems,* 1-23, doi:10.1016/B978-0-12-805317-1.00001-4.
2. *CFAES Weather System*,. https://weather.cfaes.osu.edu/ (Accessed December 4, 2023).
3. Esri, Maxar, Earthstar Geographics, and the GIS User Community, 2023: World Imagery. ESRI, accessed 1 December 2023, https://services.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer
4. Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, 2023: World Topographic Map, v2. ESRI, accessed 1 December 2023, https://basemaps.arcgis.com/arcgis/rest/services/World_Basemap_v2/VectorTileServer.
5. Florinski, I. V., T. B. Kulagina, and J. L. Meshalkina, 1994: Influence of topography on landscape radiation temperature distribution. *International Journal of Remote Sensing*, **15**, 3147–3153, doi:10.1080/01431169408954317.
6. Howe, J. A., A. P. Smith, 2021: The soil habitat, *Principles and Applications of Soil Microbiology (Third Edition)*, 23-55, doi:10.1016/B978-0-12-820202-9.00002-2.
7. Seibert, J., J. Stendahl, and R. Sørensen, 2007: Topographical influences on soil properties in boreal forests. *Geoderma*, **141**, 139–148, doi:10.1016/j.geoderma.2007.05.013.
8. U.S. Census Bureau Geography Division, 2023: 2023 TIGER/Line® Shapefiles: State. U.S. Census Bureau, accessed 10 January 2024, https://www2.census.gov/geo/tiger/TIGER2023/STATE/.
9. Wu, B., S. P. Oncley, H. Yuan, and F. Chen, 2020: Ground heat flux determination based on near-surface soil hydro-thermodynamics. *Journal of Hydrology,* **591**, doi:10.1016/j.jhydrol.2020.125578.

ACKNOWLEDGEMENTS

This research was made possible by the Ohio State Atmospheric Sciences Program and Department of Geography. Data was visualized and processed in ArcGIS Pro and using the SciPy, NumPy, and Matplotlib Python packages.