Auburn University Journal of Undergraduate Scholarship

Archaeological Modelling of Ice Patches in the Northwest Territories Using Remote Sensing and GIS

Bethany G. Foust[1] , Mallory Jordan[2], Stephanie R. Rogers[3,]*

[1] Undergraduate Student, Department of Geosciences, Auburn University
[2] Graduate Student, Department of Geosciences, Auburn University
[3] Assistant Professor, Department of Geosciences, Auburn University

Due to climate change, ice patches, glaciers, and snow are melting at unprecedented rates in high latitude and altitude environments (Ødegård et al., 2017). This phenomenon has exposed archaeological remains across the world, leading to a new field of study called "Ice Patch Archaeology" (Reckin, 2017). This study focuses on ice patch archaeology in the Mackenzie Mountains, located in the Northwest Territories (NWT), Canada (Fig. 1), where ice patches have historically been used by caribou (*Rangifer tarandus*) in the summer to escape from heat and insects (Andrews et al., 2012). Artifacts like bows, arrows, and darts have been uncovered near ice patch margins, which were left behind by native hunters and preserved for thousands of years. This study area is vast and difficult to access, therefore geospatial tools like Geographic Information Systems (GIS) and remote sensing are essential for archaeological prospection site selection. These were used to locate areas of high archaeological potential where artifacts might be freshly exposed from newly melted ice patches.

For this study, a multiscale, GIS-based multi-criteria decision analysis (MCDA) approach was used to find areas with archaeological potential and recently melted ice (Dixon et al., 2005., Rogers et al., 2014). Two models were created: Model 1 was created to first narrow down a very large study area (4,430 km^2) with a coarse resolution Digital Elevation Model (DEM, 30 m) (ASTER Science Team, 2019), and Model 2 zoomed in on an area of interest to conduct higher resolution analysis using a 2 m DEM (Porter et al., 2018). For both models, the ideal criteria for locating artifacts were determined to be areas with high caribou presence and density, elevation above 1,500 m, N and NE facing slopes, and slope angle which could be easily traversed by humans (Fig. 1A). Each criterion was classified according to its capacity to contain ice and weighted based on its relative importance to the overall model, with caribou density being most important and slope angle being least important (Fig. 1A).

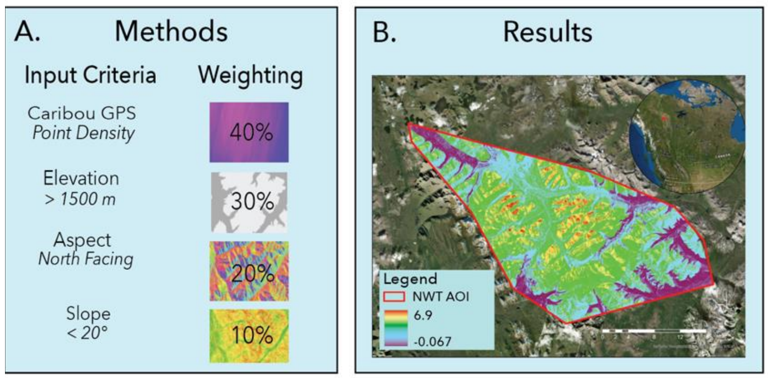

Figure 1. A.) features the ideal criteria input into the MCDA on the left, and how much each layer was weighted in its potential to house archaeological artifacts in ice. **B.)** shows the resulting map with high potential areas in red, and an inset map of the location of the study area in the Mackenzie Mountains, Canada.

Results from Model 1 enabled us to narrow down the 4,430 km^2 study area to 825 km^2 of high archaeological potential and to conduct more in-depth analyses to further refine the study area and resulting in 60 km^2 of high archaeological potential. Next, Sentinel-2 satellite imagery (European Space Agency, 2015) was used to create a Normalized Difference Snow Index (NDSI) (Gascoin et al., 2020) using green (Band 3) and shortwave infrared (Band 11) bands to locate snow and ice (Equation 1.).

$$NDSI = \frac{(Band\ 3 - Band\ 11)}{(Band\ 3 + Band\ 11)} \quad (1)$$

Equation 1. Normalized Difference Snow Index used for Sentinel-2 imagery.

Satellite imagery was obtained for September 2018 and September 2021 when there was perennial ice and snow coverage. The 2021 tile was subtracted from the 2018 tile to show areas of recent melt. Recent melt areas were compared to

* Corresponding author: s.rogers@auburn.edu

Model 2 results, and overlapping areas were designated as ideal locations (shown in red) for archaeological prospection in Summer 2022 (Fig.1B). Archaeologists will report their findings and we will use this information to further refine the model for the NWT.

Statement of Research Advisor

Bethany has conducted all associated steps of this research project including the literature review, data collection, data analysis and processing, and interpretation. This research is very important for archaeologists in the NWT, as well as around the world, for recovering culturally significant artifacts that become threatened by decomposition when they are exposed to elements after melting out of environmentally sensitive ice patches.
– *Stephanie Rogers, COSAM*

References

[1] Andrews, T. D., MacKay, G., Andrew, L., Stephenson W., Barker, A., Alix, C., & Tulita, S. E. of. (2012). Alpine Ice Patches and Shúhtagot'ine Land Use in the Mackenzie and Selwyn Mountains, Northwest Territories, Canada. *Arctic*, *65*, 22–42.

[2] Dixon, E. J., Callanan, M. E., Hafner, A., & Hare, P. G. (2014). The Emergence of Glacial Archaeology. *Journal of Glacial Archaeology*, *1*, 1–9. https://doi.org/10.1558/jga.v1i1.1

[3] European Space Agency. (2015). *Sentinel-2 MSI Level-1C TOA Reflectance* [Data set]. European Space Agency. https://doi.org/10.5270/S2_-d8we2fl

[4] Gascoin, S., Barrou Dumont, Z., Deschamps-Berger, C., Marti, F., Salgues, G., López-Moreno, J. I., Revuelto, J., Michon, T., Schattan, P., & Hagolle, O. (2020). Estimating Fractional Snow Cover in Open Terrain from Sentinel-2 Using the Normalized Difference Snow Index. *Remote Sensing*, *12*(18), 2904. https://doi.org/10.3390/rs12182904

[5] ASTER Science Team (2019). *ASTER Global Digital Elevation Model V003* [Data set]. NASA EOSDIS Land Processes DAAC. Accessed 2022-06-16 from https://doi.org/10.5067/ASTER/ASTGTM.003

[6] Ødegård, R. S., Nesje, A., Isaksen, K., Andreassen, L. M., Eiken, T., Schwikowski, M., & Uglietti, C. (2017). Climate change threatens archaeologically significant ice patches: Insights into their age, internal structure, mass balance and climate sensitivity. *The Cryosphere*, *11*(1), 17–32. https://doi.org/10.5194/tc-11-17-2017

[7] Reckin, R. (2013). Ice Patch Archaeology in Global Perspective: Archaeological Discoveries from Alpine Ice Patches Worldwide and Their Relationship with Paleoclimates. *Journal of World Prehistory*, *26*(4), 323–385. https://doi.org/10.1007/s10963-013-9068-3

[8] Rogers, S. R. (2014). An Overview of Selected GIS Methods Available for Use in Glacial Archaeology. *Journal of Glacial Archaeology*, *1*, 99–115. https://doi.org/10.1558/jga.v1i1.99

Authors Biography

Bethany Foust graduated with a B.S. degree in Geospatial and Environmental Informatics at Auburn University. She was an Undergraduate Research Fellow during her senior year in the GeoIDEA Lab. In August, she will start her M.S. degree in Geography and NSF Research Traineeship at Auburn University. Her interests include climate change, water, geography, and cartography.

Mallory Jordan is a research assistant in the GeoIDEA Lab at Auburn University. She recently completed her M.S. in Geography and will commence her PhD in Earth System Science this August at Auburn University. Her research interests revolve around the use of geospatial techniques to address environmental issues, especially those related to water.

Dr. Stephanie R. Rogers is an Assistant Professor of Geographic Information Science in the Department of Geosciences at Auburn University. She studied ice patch and glacial archaeology as part of her PhD research in the Pennine Alps in Switzerland. Dr. Rogers continues to work with archaeologists to better understand how physical characteristics of the terrain can help unlock clues to the past.