Detecting Surface Water Changes in Northern Manitoba

Using Multi-Temporal Satellite Imagery

Project Proposal

Domenica Rosina Burroughs – 3053068

GACS-7502

Dr. Liu

University of Winnipeg

Introduction

Northern Manitoba is experiencing rapid environmental changes due to climate change. The regions hydrology is being continually altered by rising temperatures and fluctuating precipitation patterns, which has significant implications for ecosystems, infrastructure, and community resilience [1], [2]. The landscape consists of lakes, wetlands, and extensive river systems, many of which are underlain by discontinuous permafrost [3]. Permafrost coverage varies by location, driving seasonal shifts in land cover. Thawing permafrost increases surface ponding, which alters vegetation and damages critical infrastructure like railways; the only consistent land access in Northern Manitoba.[3],[4]. These vulnerabilities affirm the need to understand surface water dynamics for effective mitigation and planning resilient [5]. Remote sensing, particularly through spectral indices such as the Normalized Difference Water Index (NDWI) are especially effective for identifying water bodies and tracking hydrological changes over time. Research has demonstrated the utility of NDWI-based techniques for surface water detection [6],[7]. Studies in northern regions have also shown that satellite imagery can reveal long-term trends in surface water extent, even in areas affected by permafrost [8].

This project aims to address the lack of accessible workflows for detecting surface water changes in remote northern regions using limited computing resources. It proposes a digital image processing pipeline built with open-source tools and satellite imagery to visualize and quantify changes over a five-year period. The goal is to support climate adaptation, land use planning, and infrastructure resilience in Northern Manitoba [9].

Research Aims

This project hypothesizes that a digital image processing pipeline, built using open-source tools and satellite imagery, can effectively detect and visualize surface water changes in

Northern Manitoba. By applying NDWI-based techniques and temporal analysis [10], the pipeline will reveal meaningful patterns in surface water that reflect seasonal and year-to-year variability. The research aims to develop a workflow capable of identifying and visualizing these changes, quantify spatial and temporal variations in water extent over a five-year period, and generate geospatial visualizations and summary statistics that support interpretation of hydrological trends and potential climate impacts.

Materials and Methodology

This project will be conducted using a 2013 MacBook Pro, which presents certain computational limitations. To accommodate these constraints, the analysis will focus on a five-year temporal window to demonstrate a working proof-of-concept for surface water change detection. To manage the volume of satellite imagery, an external SSD will be used for local storage and intermediate results. In cases where local processing becomes inefficient, batch processing will be implemented to reduce memory load.

The overall workflow, as illustrated in Figure 1, consists of four main stages: data acquisition, preprocessing, NDWI computation, and temporal change detection. Primary data sources include Landsat DSWE [11] maps for long-term analysis, Sentinel-2 [12] imagery for seasonal observations, and Arctic SDI [13] base map for context. The pipeline incorporates techniques such as histogram equalization, noise reduction, and NDWI to identify water bodies [10]. Temporal change detection will be performed using image differencing and thresholding methods [14]. The analysis will be conducted using Python libraries including OpenCV, Rasterio, and scikit-image, alongside QGIS for visualization and spatial analysis. [[15], [16], [17]

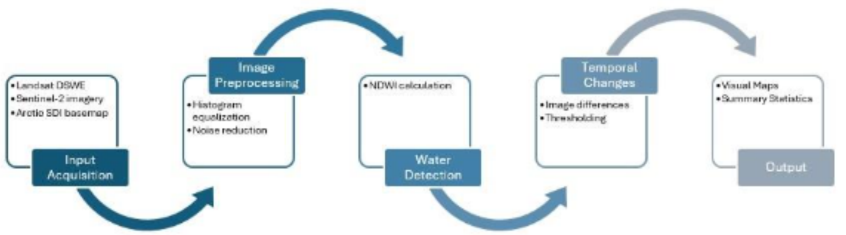

Figure 1 – Flowchart demonstrating the data flow for detecting surface water changes for this processing concept

Expected Results

The project will produce a proof-of-concept workflow capable of detecting and analyzing surface water changes. Visual outputs will include seasonal and interannual maps derived from NDWI-based water masks, illustrating patterns of expansion and contraction. Quantitative results will measure water body area over time, identify seasonal variability, and summarize hydrological trends. These outputs provide a framework for continued investigation.

Significance

Understanding surface water dynamics is essential for environmental monitoring and infrastructure planning, especially in northern regions where climate change accelerates hydrological shifts [8], [18]. This project aims to demonstrate how remote sensing analysis can be conducted on modest hardware, making geospatial analysis accessible. The workflow is designed to produce interpretable results that inform decision-making in Northern Manitoba, where infrastructure and ecosystems are sensitive to water changes.

Surface water changes also affect Indigenous communities whose livelihoods are closely tied to the land and water [1]. The project's outputs can support local governance and planning in flood-prone areas, while offering tools for community-led environmental monitoring. By fostering collaboration between Indigenous knowledge holders and local governments, the project promotes inclusive and climate-resilient land and water management [2].

References

[1] D. Runnalls, “Climate Change Impacts in Manitoba,” 2007.

[2] Firelight Research Inc. and Canadian Climate Institute, “The Impacts of Permafrost Thaw on Northern Indigenous Communities,” Vancouver, BC, 2022. [Online]. Available: https://climateinstitute.ca/wp-content/uploads/2022/06/Impacts-permafrost-thaw-Climate-Institute-Firelight-Report.pdf

[3] D. Canada, “Permafrost Thaw: Infrastructure Challenges in Northern Canada,” 2025.

[4] L. Anthony, “Arctic permafrost is thawing. Here’s what that means for Canada’s North,” 2019.

[5] A. Bartsch, T. Strozzi, and I. Nitze, “Permafrost Monitoring from Space,” *Surv Geophys*, vol. 44, pp. 1579–1613, 2023, doi: 10.1007/s10712-023-09770-3.

[6] T. V Bijeesh and K. N. Narasimhamurthy, “Surface water detection and delineation using remote sensing images: a review of methods and algorithms,” *Sustain Water Resour Manag*, vol. 6, no. 68, 2020, doi: 10.1007/s40899-020-00425-4.

[7] S. K. McFeeters, “The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features,” *Int J Remote Sens*, vol. 17, no. 7, pp. 1425–1432, 1996.

[8] I. Olthof, R. H. Fraser, J. van der Sluijs, and H. Travers-Smith, “Detecting long-term Arctic surface water changes,” *Nat Clim Chang*, 2023, doi: 10.1038/s41558-023-01836-9.

[9] G. of Manitoba, “Manitoba’s Water Management Strategy,” 2022.

[10] K. K. Purnam, A. D. Prasad, and P. Ganasala, “Water indices for surface water extraction using geospatial techniques: a brief review,” *Sustain Water Resour Manag*, vol. 10, no. 70, 2024, doi: 10.1007/s40899-024-01035-0.

[11] Earth Resources Observation and S. (EROS) Center, “Landsat Level-3 Dynamic Surface Water Extent, Collection 2,” 2022.

[12] European Space Agency, “Copernicus Sentinel-2 Satellite Imagery.”

[13] Arctic Spatial Data Infrastructure, “Arctic SDI Geoportal.”

[14] K. Tenneson and others, “Change Detection,” in *Cloud-Based Remote Sensing with Google Earth Engine*, Springer, 2023, pp. 303–316.

[15] OpenCV Development Team, “Reading Geospatial Raster files with GDAL.”

[16] Rasterio Development Team, “Rasterio: access to geospatial raster data.”

[17] QGIS Documentation Team, “QGIS User Manual: Georeferencer.”

[18] H. Travers-Smith and others, “Changes in surface water dynamics across northwestern Canada are climate-driven,” *Environmental Research Letters*, vol. 17, no. 11, p. 114021, 2022, doi: 10.1088/1748-9326/ac9c3b.