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Climate-induced Changes in the Subarctic River System: A Case Study on the Masjok River, Norway

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1. INTRODUCTION

The ongoing global warming and its arctic amplification (Previdi et al. 2021) might result in reduced hunting grounds and traditional food sources, degradation of drinking water, which pose challenges to food and water security for many indigenous communities (Richter-Menge 2011). Climate change is projected to significantly alter the hydrological cycle on a global and regional scale (Allan et al. 2020). Reduced snow cover and permafrost in Sub-Arctic and Arctic areas may impact drainage systems and river discharge (Bring et al. 2016). Future projections indicate a decline in the overall amplitude of yearly runoff as well as in the springtime intense snow melt runoff episodes (Javadinejad et al. 2020). River systems in the arctic and sub-arctic regions are extremely sensitive climate change sensors, and these fluvial systems are experiencing a shift in discharge and sediment load (White et al. 2007). The seasonal ice cover and suspended sediment concentration control the incoming solar radiation in the rivers and are considered two crucial factors that dictate the physical and biological state of the arctic rivers (Thellman et al. 2021). Climate change can trigger early meltdown of ice cover, resulting in high discharge and suspended sediment in the river (Burrel et al. 2023), which in turn determines the morphological evolution of river channels and coastal deltas. In arctic and subarctic rivers, ice cover and sediment dynamics regulate nutrients and biogeochemical cycles, affecting marine flora and fauna as well as water quality. Early arrival of spring and extended ice-free season could trigger erosion through the dynamic breakup of ice cover and make scour holes in the river banks.

The Masjok River (Fig. 1) is one of the major tributaries of the Tana River, with a catchment area of 568.11 km². This river is the main source of suspended sediments in the Tana River basin. Although there are ample examples of hydrological modelling (Moges et al. 2017) and sediment analysis (Wenng et al. 2021) in the Tana River, studies involving the Masjok River are relatively scarce in the literature. Therefore, our primary objective is to observe the river ice dynamics and seasonal changes in the ice cover in the Masjok River. We aim to establish statistically significant trends of important metrics such as dates of spring breakup and autumn freeze-up, total ice-covered days, ice cover, suspended sediment and discharge data, this project aims to examine the relationships between these three variables in the backdrop of climate change.

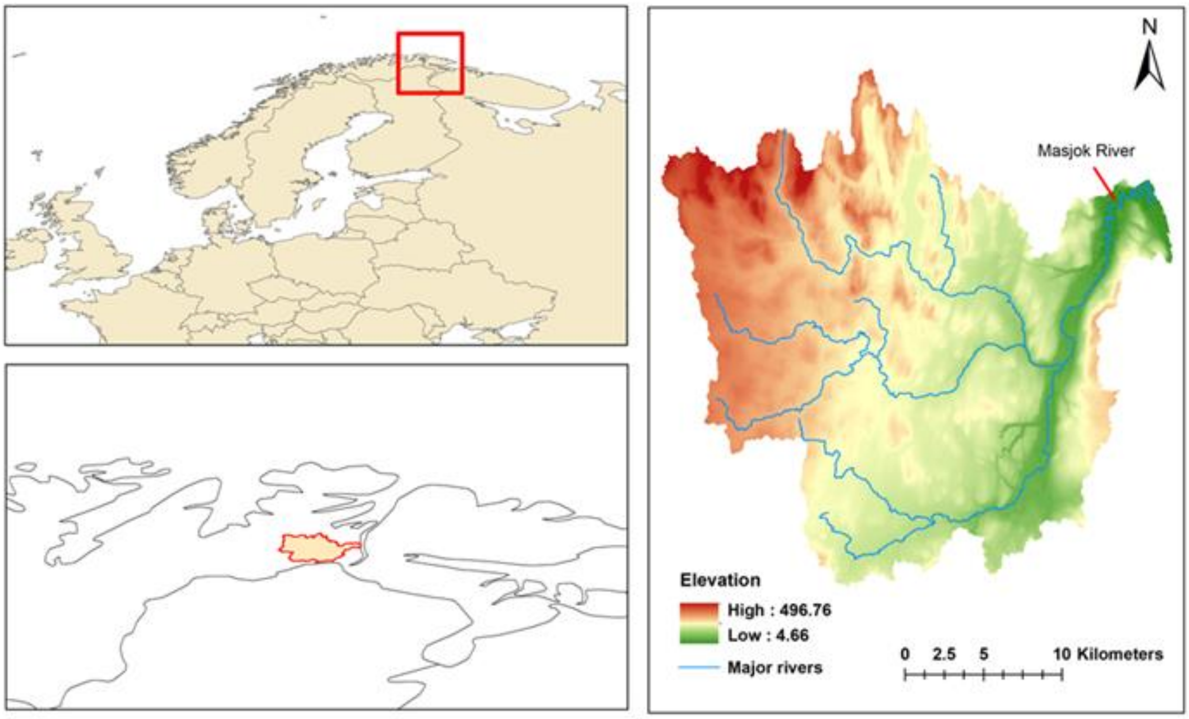

Fig. 1. Masjok River basin.

2. METHODOLOGY

The phenology of the Masjok river ice for the last 30 years was examined using Sentinel-1 C-band Synthetic Aperture Radar (SAR) data. For older periods (before 2015), in case of unavailability of Sentinel-1, Sentinel-2 MSI, and Landsat legacy datasets were consulted. Classification of river ice was based on the copolarization ratio (χ), where < 3 dB indicates open water, < –25 dB indicates thermal ice, and the values in between (from 3 dB to –25 dB) indicate consolidated ice (Mermoz et al. 2009). An extensive field campaign was performed in the lower Masjok River to collect water and sediment samples. Water samples were filtered to observe the settling velocity, and grain size analysis was performed using the laser diffraction method. Additionally, bathymetry was collected during the field visit. Time series analysis was implemented on the long-term discharge, ice cover extent and suspended sediment to find statistically significant trends. This analysis also included the Mann–Kendall test for monotonic trends and Sen's slope estimator. Then, a relationship between climatic and hydrological variables was established, which helped in understanding the physical processes in the Masjok River.

3. RESULTS

This study captured the accelerating trend of the longer ice-free days in the Masjok River and surrounding areas and their relation to increased suspended sediment concentration. Our study revealed that the ice-free days have been continuously increasing in the past 30 years. Modelling efforts in the past also predicted a similar kind of observation for the years 2070–2100, especially the TANAFLOW model by Dankers and Christensen (2005), where the snow-free season was reported to extend by 41 days based on the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES). Moreover, the scour holes from the in-situ observation were hypothesised as the mechanical movement of dynamic ice break-up and similar observations were also reported by Eilertsen and Corner (2011) in the same area. The sediment pulse measurement provided an accurate time and process of the ice breakup in the Masjok River basin, where the observed sediment load was highest in the early spring and lowest in winter. In a recent experiment, Blåfield et al. (2024) also found similar observations at the Pulmankijoki River, another tributary of the Tana, located in the same region. The sediment load was also found to be highly seasonal, with higher concentrations of suspended sediment in autumn and winter and lower in spring and summer, which is corroborated by scenario-based modelling efforts (Lotsari et al. 2010).

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