Climate records for Fairbanks (UAF Experiment Station) from 1904 to 2019 were acquired from the National Oceanic and Atmospheric Administration (https://www.ncdc.noaa.gov/cdo-web/). Additional data were obtained for the Nenana station (about 70 km southwest of Fairbanks), to fill in small data gaps (particularly precipitation/snow depth ruler measurements) in the Fairbanks record. We attributed the data with fields for summer (May-September) and winter periods (October-April) and hydrologic year (October-September) and calculated mean air temperature, precipitation, and snow depth by seasonal period (average of daily values) and year. The broad summer and winter periods were of interest because warmer and wetter summers increase soil heat input and warmer and snowier winters reduce soil heat loss.

Plant cover was determined by point-sampling at 100 points (including repetitive “hits” for all layers) distributed along 5 equally spaced rows (4-m long, 20 points per row) across the 10-m long plot. The plots were examined for additional species and a cover of 0.1% was assigned to all species not captured in the point sampling. Taxonomy follows that of the Flora of Alaska provisional checklist (https://floraofalaska.org/provisional-checklist/).

Water levels and temperatures of near-surface groundwater at two parallel, 15-km-long fens (three sites each) and a small lake were measured hourly from summer 2011 through early fall 2014 using non-vented pressure transducers (HOBO U20 Fresh Water Level Data Logger 13 feet, U20-001-04, Onset Hobo Company, Bourne, Massachusetts). They were deployed inside a 4-cm-diameter perforated PVC pipe situated at least 10 m from the fen margin. The sensors rested on top of a 1-cm-diameter steel rod with a 3-cm-diameter cap. The rod was pounded into the sediments below the floating mat with a slide hammer to a depth greater than the typical seasonal freeze-thaw depth in the area (usually 1.5 m) to avoid jacking from seasonal frost. The sensors were between 1 and 1.5 m below the water level in the fall and secured to the top of the pipe with a slacked line for retrieval. Barometric pressure measurements were made using an additional sensor hung from a tree at the Lake, Fen 1\_Mid, and Fen 2\_Upper sites. Elevations of the sensors were determined using a high-resolution, differential global positioning system (DGPS). Based on the measurement error for the z coordinate direction with the DGPS and the pressure transducer (+/-0.3 cm of water) we estimate the vertical water level elevation error to be +/- 4 cm. Wells were accessed via helicopter (summer) or snow machine (winter) for downloading and maintenance.

For data processing and analysis, we used HoboWare (Onset Computer Corporation, Bourne, Massachusetts) for initial processing and barometric pressure correction and the data were compiled into an Excel database. To allow comparison of water-level trends among sites, the long-term mean water surface elevation (WSE) of each site (ranging from 128.48 m to 162.58 m amsl) was subtracted from the hourly readings to provide a normalized stage (above and below average reference height). Mean daily water levels and temperatures were calculated and plotted to examine temporal trends.

We developed a time-series of geo-rectified historical airphotos and recent high-resolution satellite imagery to quantify areal changes in fens on the Tanana Flats using ArcMap. We identified three fen systems on the central portion of the Tanana Flats and digitized a center line through the fens based on the 1978 imagery (Figure 2). We subdivided the fens into a wider lower part and a narrower upper part with the hypothesis that lateral fen degradation may be more rapid in the wider, lower portions of the fens presumably caused by higher groundwater flow. For systematic measurement of fen widths we subdivided the center lines of the three fens into either 400 or 600 m segments depending on fen length to provide similar sample sizes (n=25 to 35). Fen widths were then measured at the end of each segment. For each time period and sampling location we drew a line perpendicular to the centerline extending from western margin of the fen to the eastern margin. Fen margins were interpreted from the imagery and in most cases were distinctly evident as a sharp boundary between birch or spruce forest (individual trees were evident on the high resolution imagery) and the herbaceous fen. In some cases, we differentiated low scrub on permafrost plateaus from fens. Occasionally, the margins were patchy and transitional; in these situations we visually interpolated an outer margin across discontinuous permafrost patches. Also, in some cases the 1949 airphotos were of such low quality that a reliable interpretation was not possible; in these situations we assigned the 1949 margin to be the same as the 1978 position, leading to a slight underestimation of the change from 1949 to 1978. The line segments were attributed with year, fen number (13), fen size (L, S), segment, and point ID (PtID, concatenated fen number, segment number, and year). We also noted whether there were forested islands present within the fens and if permafrost aggradation had occurred as indicated by newly developed permafrost plateaus within the fen system. We interpreted rapid transition from fens to birch forests to be a conclusive indicator of permafrost aggradation because the floating fen mats are too loose and submersible to support trees.

For the image analysis we obtained scanned images of black and white airphotos (1.3 m pixel resolution) from Aug. 1949 and color-infrared airphotos (1.7 m) from 7/11/1978 from the EarthExplorer web server maintained by the U.S. Geological Survey (https://earthexplorer.usgs.gov/). A black and white orthophoto-mosaic (1.0 m) produced by AeroMap for U.S. Army Alaska in 1999 was used as the basemap for georectifying imagery from other periods. High-resolution satellite imagery included a pansharpened IKONOS image (1.0 m) from 8/21/2003 and a pansharpened WorldView3 image (0.38 m) from 7/18/2018. We georectified the images to the 1999 orthophoto mosaic using ArcMap using distinctive features evident on the 1999 imagery as ground control points (usually ~20 points). The imagery was then rectified to the base images using second-order polynomial transformations, with rms errors ranging from 0.5 to 1.8 m. Co-registration errors were not a factor in the analysis, however, because the analysis depended solely on width measurements. The effects of varying spatial resolution (0.381.7 m) also was negligible because the resolutions differences were small relative to the overall change in mean fen widths (49.3 m) over the entire period.