ADVANCING EARTH AND SPACE SCIENCE

Geophysical Research Letters

RESEARCH LETTER
10.1029/2022GL100913

Wood-Based Carbon Storage in the Mackenzie River Delta: The World's Largest Mapped Riverine Wood Deposit

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Key Points:

- We use remote sensing and deep learning to measure wood-based carbon in an Arctic delta, filling an important gap in carbon cycle estimates
- The Mackenzie River Delta stores over 400,000 wood deposits in the delta totaling 3.1×10^{12} g-C
- Measured wood ages estimated from radiocarbon are younger than other river carbon pools, with ~40% of the samples still growing after 1955 AD

Supporting Information:

Supporting Information may be found in the online version of this article.

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Citation:

Sendrowski, A., Wohl, E., Hilton, R., Kramer, N., & Ascough, P. (2023). Wood-based carbon storage in the Mackenzie River Delta: The world's largest mapped riverine wood deposit. *Geophysical Research Letters*, *50*, e2022GL100913. https://doi.org/10.1029/2022GL100913

Received 31 AUG 2022
Accepted 19 JAN 2023

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Abstract

The Mackenzie River Delta (MRD) has been recognized as an important host of river-derived wood deposits, and Mackenzie River wood has been found across the Arctic Ocean. Nevertheless, we lack estimates of the amount of carbon stored as wood and its age in the delta, representing a gap in carbon cycle estimates. Here, we use very high-resolution satellite imagery and deep learning to map wood deposits in the MRD, combining this with field data to measure the stock and age of wood-based carbon. We find >400,000 individual large wood deposits, collectively storing 3.1×10^{12} g-C, equating to 2×10^{6} g-C ha^{-1} across the delta. Sampled wood pieces date from 690 AD to 2015 AD but are mostly young with ~40% of the wood samples formed after 1955 AD. These estimates represent a minimum bound on an important surficial, potentially reactive, carbon pool compared to other deeper carbon stocks in permafrost zones.

Plain Language Summary

The Arctic is warming rapidly, and this can increase landscape erosion. Consequently, carbon can be transferred into rivers and transported toward the Arctic Ocean. To date, work has tracked finer material dissolved in river water and the size of sand grains but has missed large pieces of wood that fall or slide into rivers. Wood is an important carbon-rich material that may break down differently from the finer carbon pools, however, the amount of wood stored in Arctic river deltas has not been measured before. We also don't know the age of wood in those deposits. Here we study the Mackenzie River Delta, where river-sourced wood is common and deposits extensive. We use very high-resolution satellite images which show individual pieces of wood and use a machine learning technique to map wood across the delta. We also visited the deposits to measure their size and collected samples for radiocarbon dating. We find the wood is very young compared to other carbon pools carried by the river, and that the stocks of carbon are regionally important. Our work calls for further work to understand this overlooked carbon pool in river deltas and coastal regions of the Arctic.

1. Introduction

Carbon-rich organic matter associated with large wood (LW, pieces >10 cm in diameter and 1 m in length) transported by rivers has remained an unconstrained component of carbon cycling estimates, in terms of its stock in the landscape, residence time, and flux (Kramer & Wohl, 2017). Arctic rivers account for ~15% of global drainage area and, although much of this area is not forested, there is evidence for long-term wood storage in Arctic environments (Müller, 1962) and supply of driftwood to coastal and marine environments. For example, recent work demonstrates widespread transport of wood supplied by rivers across the Arctic Ocean (Hole et al., 2021). Across the Arctic, permafrost regions currently contain more stored carbon than is in the atmosphere (Schuur et al., 2015), with Arctic deltas containing 91×10^{15} g-C stored in permafrost soils (Hugelius et al., 2014). With climate change expected to increase rates of permafrost thaw that will increase erosion rates (Lininger & Wohl, 2019), modifying delta channel networks, floodplains, and carbon fluxes and ultimately releasing legacy carbon stored in deltas (Schuur et al., 2015), previous work on carbon cycling by Arctic rivers has only focused on characterizing the source, age, and transfer of dissolved carbon species (Raymond et al., 2007; Schwab et al., 2020; Tank et al., 2012) and particulate organic carbon (Hilton et al., 2015; McClelland et al., 2016; Schwab et al., 2022), leaving out a potentially important carbon stock in the landscape.

The stocks and fluxes of LW in rivers are challenging to quantify (Kramer & Wohl, 2017) and thus constitute a missing component of global carbon cycling estimates. The residence time of LW storage in fluvial systems

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is also poorly constrained (Wohl, 2017). These gaps limit comparisons with other carbon stocks and fluxes and prevent quantitative assessments of what drives LW dynamics. After entering river corridors via bank and hillslope erosion, wood can be mobilized and rapidly transported downstream, delivering carbon to the ocean (Kindle, 1921; West et al., 2011) as LW averages ∼50% carbon by weight (Thomas & Martin, 2012). Most LW, however, moves episodically downstream and can remain in the surface or subsurface (Collins et al., 2012; Latterell & Naiman, 2007) along a river corridor for thousands to millions of years (Guyette et al., 2008; Lee et al., 2019; Müller, 1962; Nanson et al., 1995), forming an important carbon sink and altering river process and form that enhances carbon storage in floodplain soils (Sutfin et al., 2016).

Deforestation has reduced wood recruitment to many river corridors and LW has been actively removed by human action from channels and floodplains for centuries (Montgomery et al., 2003; Wohl, 2014). Consequently, LW and associated carbon dynamics have been substantially disrupted, especially in rivers of the temperate latitudes. Some Arctic rivers still retain more natural LW fluxes and storage, including the Mackenzie River, which is known for substantial wood fluxes to the Arctic Ocean (Eggertsson, 1994; Kindle, 1921), and its delta, which contains extensive wood deposits. This globally relevant system provides an opportunity to quantify fluvial wood-carbon storage and compare these values to quantitative estimates of soil carbon storage. Here, we analyze very high-resolution satellite imagery using machine learning approaches combined with field measurements of wood volumes and radiocarbon dating to quantify LW stocks and ages in a large Arctic river delta (Figure 1).

2. Materials and Methods

2.1. Site Description

The Mackenzie River exports significant amounts of dissolved and particulate carbon and LW to the Arctic Ocean through the Beaufort Sea (Hilton et al., 2015; McClelland et al., 2016; Raymond et al., 2007). Wood in the river is transported seasonally during ice break up with summer high flows, though exceptional volumes of wood are transported episodically in events termed "wood floods" associated with summer flows of higher recurrence intervals (typically >5 years) that quickly access and transport large volumes of wood stored along banks from previous years (Kindle, 1921; Kramer et al., 2017). The head of the Mackenzie River, Great Slave Lake, receives substantial amounts of LW from the Peace and Athabasca Rivers via the Slave River. Most of this wood remains in the lake, and thus most wood entering the Mackenzie River Delta (MRD) is sourced from the Liard River (Kramer & Wohl, 2015). Some additional wood is sourced from mainstem of the Mackenzie and the Peel and Arctic Red Rivers mainly through slumping and ice gouging of banks. However, the wood sourced from these more northern reaches are much smaller than the plethora of very large logs sourced from the more southern headwaters of the Liard.

The delta is the second largest Arctic delta in land area and the third largest in drainage basin size (Piliouras & Rowland, 2020), totaling over 13,000 km^2 (Figure 1). It contains complex distributary channel networks and floodplains that form an extensive mosaic of LW depositional areas including channel banks, lake shores, inland floodplains, and coastal bays. Quantifying the extent of LW storage can be difficult due to the heterogeneous depositional sites and processes that influence LW dynamics. To quantify the extent of LW storage, we conducted field reconnaissance (Section 2.2) of deposits throughout the delta and then used the information from the field to inform a remote sensing survey (Section 2.3) of the entire delta.

2.2. Field Reconnaissance

Forty-two wood deposits were visited in August 2019 (Figure 1, Table S1 in Supporting Information S1), with several more visually surveyed using drone and low-flying aircraft in the same period. Field locations were chosen based on accessibility and an effort was made to visit multiple depositional environments, including lake shores, coastal embayments, inland floodplains, and riverbanks. Where possible, wood deposit extent was measured at each sample site using a tape measure. Deposit thicknesses and porosity were estimated as an average of several points taken at intervals along transects traversing the deposits (perpendicular to orientation of logs). These porosity and depth estimates were used to calculate total volume of wood using the aerial extent method (Livers et al., 2020) (Table S3). For further discussion of field measurements, see Text S2 in Supporting Information S1.

At each site, up to three samples of wood were collected for radiocarbon analysis, usually from proximal to distal of river flow for the channel bank deposits, from the shore inland for the coastal sites, or along a transect for the inland deposits. Due to wood weathering, extracting sub-samples from a deposit was often difficult, and using a wood corer was not practical. Instead, an axe was used to recover the outermost wood (around 2–5 cm) from LW pieces without

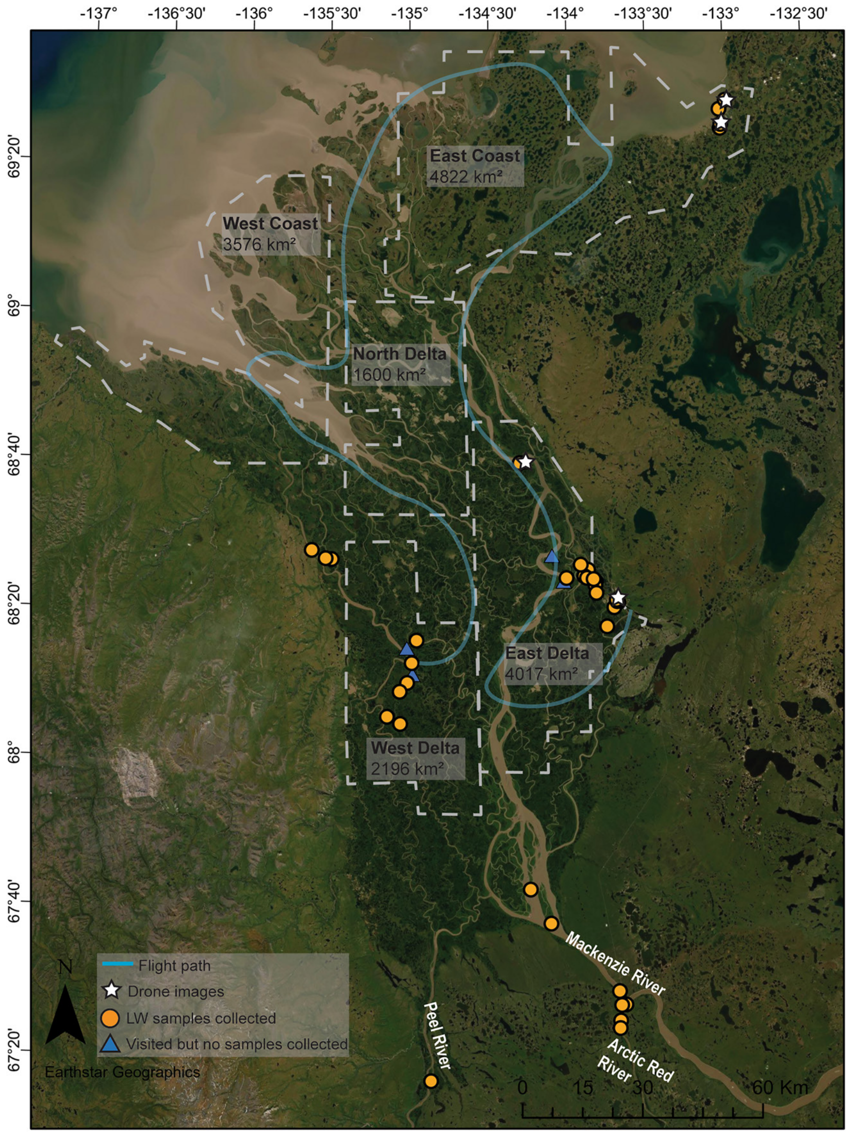

Figure 1. Map of the Mackenzie River Delta (MRD). Map of the Mackenzie River Delta showing the boundaries of satellite images classified. Areas outside of these boundaries either had no available imagery, or the classification was very poor. The major delta distributaries are also labeled, as are the locations of field site visits where large wood samples were collected (orange circles) and sites were visited but no samples collected (blue triangles). Locations with drone images are also shown (white stars). The blue line shows the approximate flight path of a low flying aircraft flown around the delta where additional imagery was collected.

bark, as such providing constraint on the age of the most recent growth rings prior to tree death. However, in an effort to find the ages of the oldest wood in the delta, some samples consisted of loose wood pieces or decaying logs where the outer ring was not likely sampled. These are noted in Table S4 and Hilton et al. (2023). This sampling of wood was systematic to target the multiple depositional environments visited and provide robust spatial coverage with samples ranging from 132 to 135W and 67 to 69N. Additional details are provided in Text S2 in Supporting Information S1.

2.3. Quantifying Wood in Imagery

2.3.1. Imagery Information

Very high-resolution (VHR) satellite imagery was obtained from Maxar Inc. via the Polar Geospatial Center (PGC) at the University of Minnesota. The PGC orthorectified and pansharpened all images to achieve multispectral

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images at the highest resolution available. In total, 60 cloud-free images of the delta were analyzed, taken from GeoEye, Quickbird, WorldView-02, and WorldView-03 satellites that span 2009–2021 (Table S2 in Supporting Information S1). Each image covers an area of approximately 350 km^2 and has a resolution of 0.30–0.65 m. Images analyzed covered 87% of the delta.

2.3.2. Image Classification

Semantic segmentation, a deep learning approach that uses a convolutional neural network (CNN) to classify pixels in an image, was used to quantify wood extent in the imagery. A binary classification scheme was used to identify "wood" and "not wood." The CNN was trained using 20 images taken across the delta with equal representation of the four satellites, hand labeled for wood and non-wood pixels. The model was trained in Matlab on the RMACC Summit supercomputer at the University of Colorado Boulder. Accuracy was assessed using the confusion matrix. See Figure S1 and Text S3 in Supporting Information S1 for further model training information, accuracy assessment, and post-processing procedures. The post-processed output binary maps of wood and non-wood pixels were used to find wood extent across the delta.

2.4. Conversion to Carbon Stock

Wood aerial extent was converted to carbon weight via the formula:

$$X = A_{\mathrm{LW}} \ast z \ast (1 - p) \ast \rho \ast a \ast 1000$$

Where X is carbon stock in g-C, A_{LW} is wood aerial extent in m^2, z is wood deposit thickness in m, p is porosity of the deposit, ρ is the wood density (500 kg/m^3), and a is the fraction of carbon in wood (0.48). Wood volumes and carbon weights were calculated for the entire wood deposit and then split regionally by area to focus on differences in wood deposit area and density by region (dashed boxes in Figure 1). An expanded description and results are provided in Text S4 in Supporting Information S1 and Table S3.

2.5. Radiocarbon Measurements and Calculation of Calendar Age

Wood samples taken in the field were sub-sampled to capture several years of growth rings. Where possible, the outer ring was retained. These samples therefore represent the most recent part of the tree's growth. Cellulose was extracted from each wood sample for radiocarbon (^{14}C) measurement at the NEIF Radiocarbon Laboratory, SUERC, East Kilbride, UK. The measured cellulose conventional radiocarbon years BP and F^{14}C values and their analytical uncertainties were used to model the date of the wood sample (in calendar years AD). All ages were modeled in OxCal version 4.4 (https://c14.arch.ox.ac.uk/oxcal.html#program) (Ramsey, 2009). See Text S5 in Supporting Information S1 for expanded description of radiocarbon analysis.

To allow a comparison of estimated wood ages across the whole sample set, we plot the probability distributions of age from OxCal, organized by the geographic location (Figure 4). While this is a non-standard way of visualizing radiocarbon dates, our purpose here is not to provide an absolute chronology, and instead to (a) capture the range of uncertainty on dates for any given wood sample, while also (b) allowing us to assess the overall distribution across the sample set.

3. Results

3.1. Wood-Based Carbon Stock in the MRD

Of the classified area, unvegetated wood covers 51.8 km^2 of the delta and is composed of 414,800 individual wood deposits >1 m^2 visible from satellite imagery (Figure 2). We estimate an overall unvegetated LW volume of $13 \pm 8 \times 10^6$ m^3, considering the variation in potential deposit thickness and porosity. This volume results in a wood-based carbon pool of 3.1×10^{12} g-C with a per hectare value of 6×10^8 g-C/ha for wood area and 2×10^6 g-C/ha for the delta area. These values reflect visible wood within the active layer overlying permafrost and are a minimum bound of wood-based carbon storage, as we lack information on LW volumes obscured from satellite imagery under vegetation canopy, submerged along the coast and in lakes and channels, and buried. Many of the wood deposits visited in the field were under canopy cover, especially in the western part of the delta (Figure 2d). From these insights, we estimate that the active layer "unseen" carbon pool is quite extensive and therefore a true value of $>5 \times 10^{12}$ g-C is likely more accurate.

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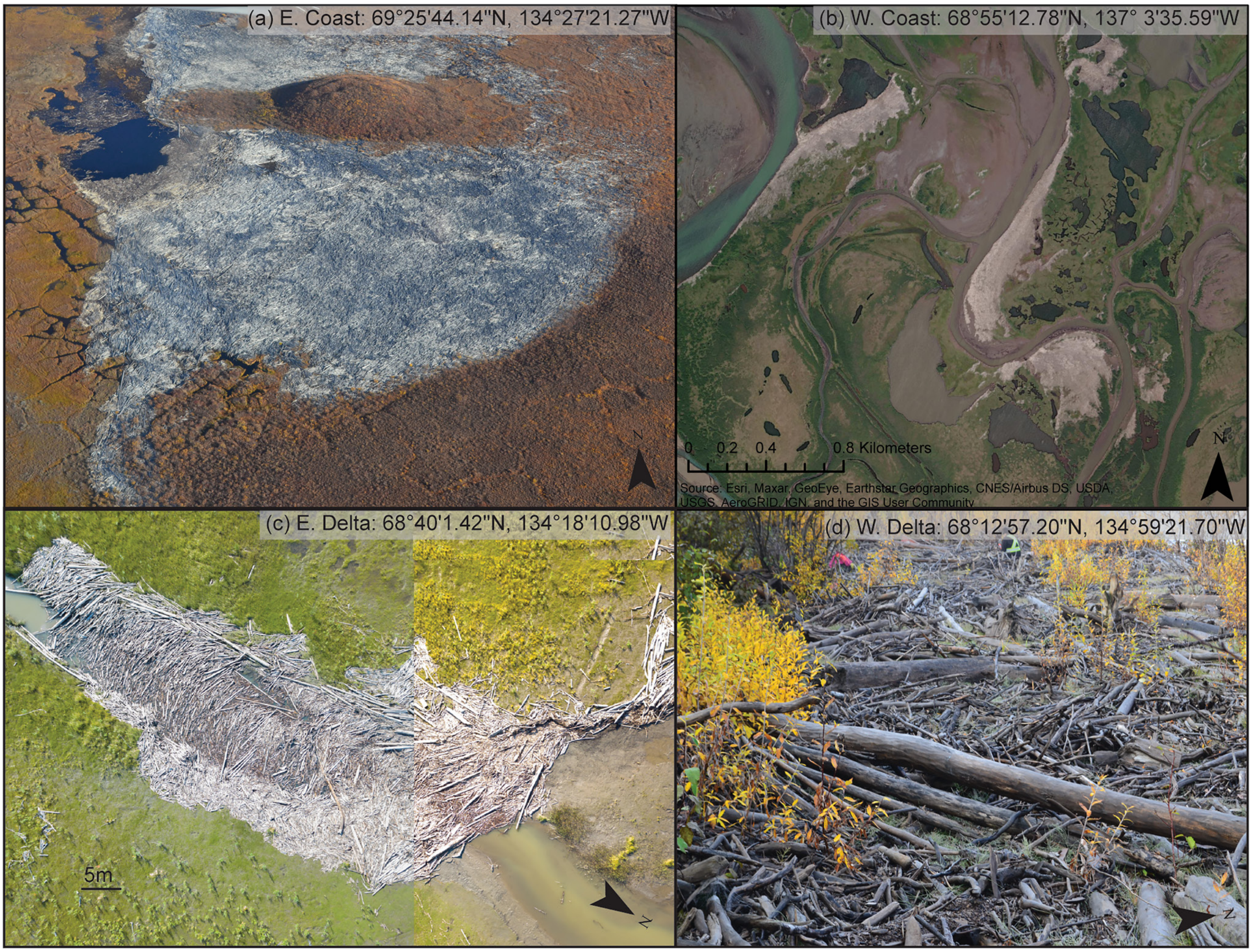

Figure 2. Examples of deposits around the delta. (a) The largest wood deposit in the delta. Photo taken from an airplane flying at 300 m above the ground. (b) GeoEye satellite image from July 2011 of wood deposits along the western coast. The white areas are the wood. Image copyright Maxar 2011. (c) Drone image of a wood raft in the eastern part of the delta, taken from a height of 30 m. Image shown is stitched from two drone photos. (d) Ground image of a wood deposit in the western part of the delta. This photo only shows about 1/4 of the total deposit length. Kneeling person at rear center for scale.

3.2. Spatial Distribution and Age of Wood-Based Carbon Pools in the MRD

Nine of the ten largest wood deposits are located along the coast (Figure 3), with six located along the eastern coast and three along the western coast (Figure 1). Most carbon deposits contain between 10^6 and 10^7 g-C in all regions (Figure 3), but the single largest deposit, along the eastern coast, contains 6.7×10^9 g-C and covers an area of 112,600 m^2 (Figure 2a). The western coast contains 48,000 more deposits than the eastern coast in a smaller area and thus has a higher density of carbon pools (inset of Figure 3).

The eastern delta (area along the mainstem Mackenzie River) contains the most LW carbon deposits with a deposit density comparable to the western coast. The north and west delta regions have the fewest deposits although deposit densities are higher than the eastern coast. Wood in the western delta is mainly delivered via the Peel River (a smaller source area compared to the Mackenzie Basin) and most deposits surveyed in this area were under canopy cover (example in Figure 2d) thus explaining the smaller visible carbon pool in that region.

The radiocarbon content of wood samples was used to calculate the calendar age of wood deposited in the delta region. This provides some constraint on the potential residence time of wood in the fluvial system. Across the LW sample set, radiocarbon results demonstrate that approximately 40% of the measurements (30/77) are from trees that started to grow after AD 1955 (Figure 4). As such, the wood is much younger than the other pools of finer sedimentary organic matter carried by the Mackenzie River system (Figure 4a and Hilton et al., 2015). For

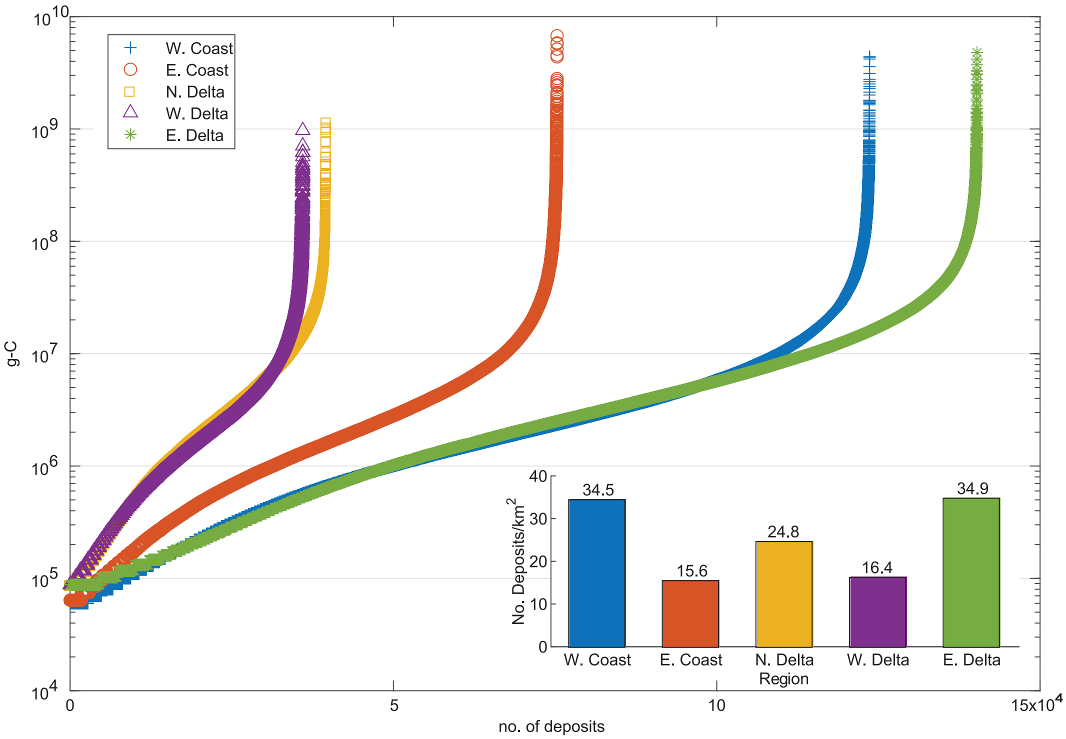

Figure 3. Wood distribution. The distribution of carbon stored in wood deposits for each delta region. These values reflect carbon storage for mean deposit thickness (50 cm) and porosity (0.5). Inset graph shows the number of wood deposits per square kilometer for each delta region.

instance, discrete organic matter and mineral-associated particulate organic carbon in the river system is typically several thousand years old, while river suspended load rich in cm size vegetation debris still has bulk radiocarbon values much lower (i.e., older) than the wood samples measured here (Schwab et al., 2022). While some individual wood deposits have similar $F^{14}C$ values and modeled ages, others have large differences between pieces. Here we only focus on the overall age distribution of wood across the delta, and do not carry out any further site-based analysis.

The youngest LW is found in the eastern delta, but post-1955 wood is also common in the western delta (Figures 4c and 4d). The Mackenzie River just upstream of the delta transports some very young wood (Figure 4b). Although only a limited number of samples are from the river inputs, it does appear that there is a higher probability of wood having an age between 1950 and 1980 in the delta. The oldest sample is from the Peel River (calibrated age 690–975 AD) but is in fact much finer samples of woody debris rather than a LW piece (Hilton et al., 2023). The coastal sites (measured only for the eastern coast) also contain young wood, but have a wider range in ages, suggesting longer residence times (or time spent in the watershed since tree death) for wood in this region. We note that the ages represent a minimum bound on wood age because we did not sample buried wood but did sample partially buried and highly decayed logs. In contrast, analysis of buried driftwood pieces taken from a pingo along the coast in the delta found ages spanning 12,000 to 33,000 years old (Müller, 1962).

4. Discussion

4.1. Comparison With Wood-Based Carbon Stocks at Lower Latitudes

The Mackenzie wood accumulations in the delta are much larger than other published values for wood deposits (Table 1). This is partly related to the vast contributing upstream drainage area of the Mackenzie basin. Although we cannot constrain wood flux with satellite imagery (Sendrowski & Wohl, 2021), we note that the wood stocks in the delta are of similar magnitude to the annual riverine exports of dissolved and particulate dissolved organic carbon to the Arctic Ocean by the Mackenzie River of 1.4×10^{12} g-C yr^{-1} (Raymond et al., 2007) and $\sim 2.2 \times 10^{12}$ g-C yr^{-1} (Hilton et al., 2015), respectively. The pan-Arctic delivery of riverine dissolved and particulate organic

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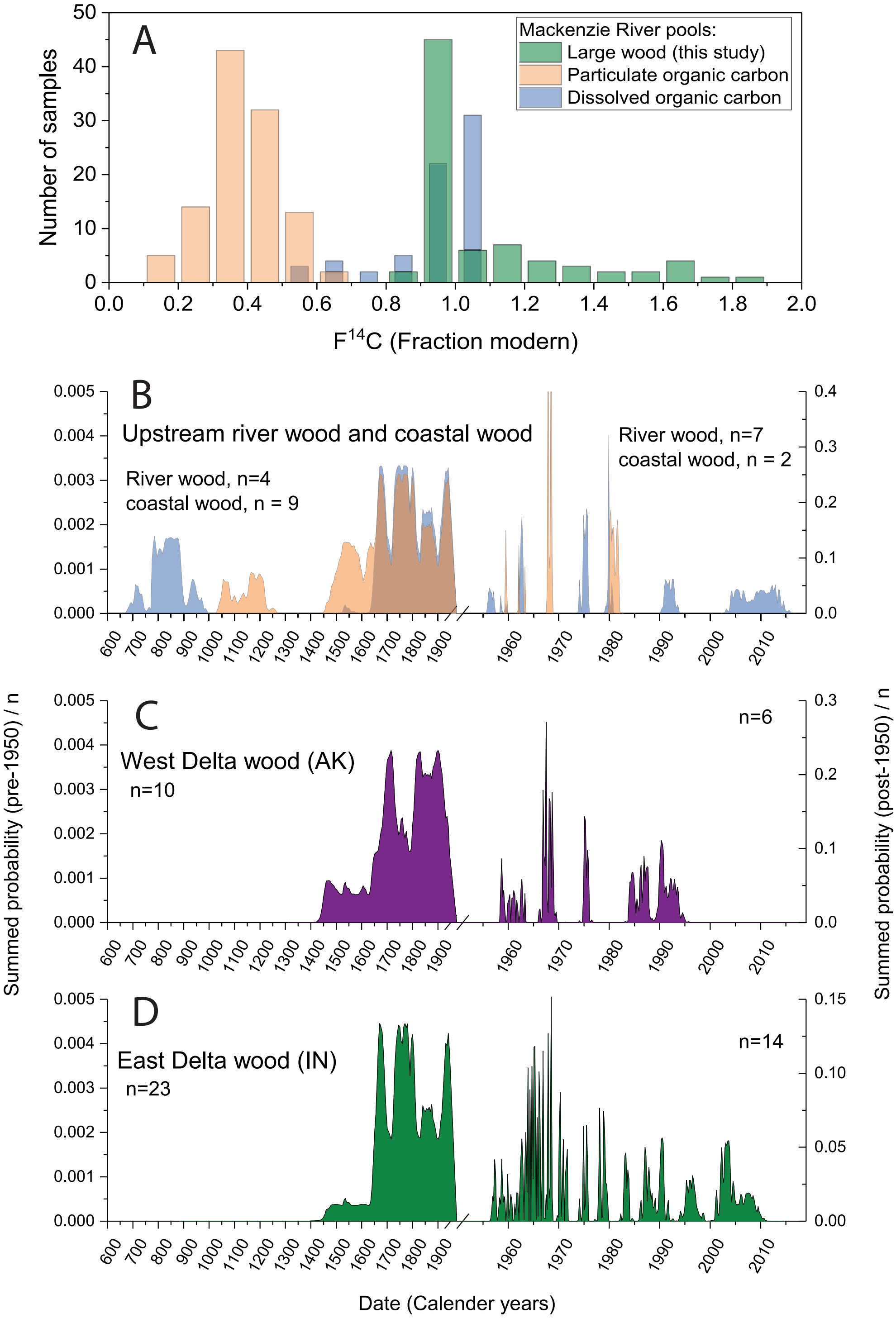

Figure 4. Radiocarbon constraint on wood ages in the Mackenzie Delta region. (a) Radiocarbon activity reported as Fraction Modern for wood samples from this study shown with samples from other river-borne organic carbon pools: particulate and dissolved (Schwab et al., 2020, 2022). (b) Radiocarbon activity used to quantify wood age, with summed probability distributions of calibrated age from OxCal 4.4 for individual samples for pre-1950 (left side, calibrated to IntCal) and post-1950 (right side after scale break, calibrated to Bomb21NH1), normalized to sample numbers (n), for wood from upstream rivers (blue) and coastal samples (orange). Where probability distributions do not reach zero at 1950, these measurements extend past the IntCat20 calibration curve and no upper age estimate is reported (Table S3). Parts (c) and (d) as part (b) but for the western Delta (purple) and eastern Delta (green). Note: The Y and X axes are different for the pre and post 1950 in order to be able show the pre-1950 data. The summed probabilities for the pre 1950 data is three orders of magnitude smaller than the post 1950 data.

Table 1
Published Descriptions of Carbon Flux and Storage in the Mackenzie Drainage Basin and Other Large Wood Deposits Worldwide[a]

Site	Description	Wood volume (m^3)	Carbon stock, Tg C (Mg C/ha)	Catchment area (km^2)	References
Mackenzie Basin Carbon-Fluxes					
Mackenzie River, Canada	Yearly POC flux by river		2.2	1,800,000	Hilton et al. (2015)
Mackenzie River, Canada	Yearly DOC flux by river		1.4	1,800,000	Raymond et al. (2007)
Slave River, Canada	Wood flood	5,000,000	1.2	600,000	Kramer et al. (2017)
Mackenzie Basin Carbon- Storage					
MRD, Canada	C-storage in delta soils to 1 m depth		68 (52.3)	1,800,000	Hugelius et al. (2014)
MRD, Canada	Unvegetated wood in delta	13,000,000[d]	3.11 (600[c])	1,800,000	This study
Great Slave Lake, Canada	Unvegetated wood along lakeshore	1,000,000–10,000,000	0.01–1 (21.7–217)	600,000	Kramer & Wohl (2015)
Other Wood Accumulations					
Red River, USA	Historic in-channel raft		0.07 (481)	236,000	Triska (1984)
Saint-Jean River, Canada	Three in-channel rafts	17,180[b]	0.004 (286)	1,130	Boivin et al. (2015)
Various locations	Floodplain wood storage		(0.8–2500)	Various	Sutfin et al. (2016)

[a]Assuming 48% carbon content in wood and 500–600 kg/m^3 wood density. [b]Assumed raft porosity of 89.5%. [c]Numbers are for wood area and not whole delta. [d]Assumed raft porosity of 50%.

carbon is estimated to be 25–36 × 10^{12} g-C yr^{-1} (Raymond et al., 2007) and 5.8 × 10^{12} g-C yr^{-1} (McClelland et al., 2016), respectively.

Despite the similarity in the stock magnitude to other organic carbon transfers in the Mackenzie River basin, the carbon stock is lower than other pools (Table 1). The total carbon pool stored in soils to 1 m depth in the major Arctic river deltas is estimated at ∼3 × 10^{16} g-C (Hugelius et al., 2014; Schuur et al., 2015), with an average 52.3 × 10^6 g-C/ha. Using 13,000 km^2 for the Mackenzie Delta area (Hugelius et al., 2014), this equates to ∼68 × 10^{12} g soil carbon to 1 m depth and 34 × 10^{15} g soil carbon total in the Mackenzie Delta. By comparison, the estimated 3.11 × 10^{12} g-C stored in surficial visible wood within the Mackenzie Delta is ∼5% of the surface soil carbon stock in the delta. However, this pool may contribute disproportionately to ocean carbon transfers and/or degradation of organic matter in the surface sediments of the delta. This could be regionally important as the estimated wood carbon storage represents a minimum value for a single major Arctic river delta that contributes just under 10% of total annual mean river discharge to the Arctic Ocean (Whitefield et al., 2015). Based on this consideration and the ecological importance of driftwood in freshwater, terrestrial, coastal, and marine environments (Wohl & Iskin, 2021) and its wide-reaching transport around the Arctic (Hole et al., 2021; Schreiner et al., 2013), we suggest that large wood retained within deltas represents an important portion of the carbon cycle of the Arctic.

The apparent young age of this LW carbon stock in the Mackenzie delta also has carbon cycle implications. Although fine grained organic matter in peat soils and river sediments persists over thousands of years (Schwab et al., 2022), the LW in surface deposits of the delta region is very young (Figure 4). We cannot determine the time of erosion of each piece of LW, but we note that 40% of the samples grew after 1955 AD, and a further 20% have upper calibrated ages younger than 1919 AD. This could reflect a majority of the LW in the delta being recently eroded and transported (if average tree lifespans are about ∼80 years, for instance). A short residence time of LW raises questions about its fate. First, the young wood ages could indicate rapid and efficient throughput of LW in the delta and that a large proportion of the LW flux (which remains unknown) enters the Arctic Ocean. Alternatively, short carbon residence times could reflect a rapid degradation of the wood material, potentially releasing CO_2 that had relatively recently been sequestered by photosynthesis from the atmosphere. Some large wood must escape degradation in the delta, as documented by the pan-Arctic transport of driftwood within sea ice: Mackenzie-derived wood reaches Greenland and Alaska's Beaufort Coast and wood from Siberia reaches Svalbard and eastern Greenland (Hellmann et al., 2013; Hole et al., 2021). Third, deep wood may persist for much longer periods of time, and the stock of LW buried in the delta away from these surficial deposits visible in satellite imagery (Figure 2) could be much larger. These pathways remain unconstrained, and our observations call for further work to establish the fluxes and fates of LW in large river deltas.

4.2. Implications for Future Change

As permafrost thaw threatens large carbon releases in Arctic systems, climate change will also influence the large wood carbon pool. Wood supply to the MRD may change in response to alterations to precipitation patterns, ice breakup, and river discharge, which act to recruit wood to river corridors and transport it downstream. Within the delta, sea level rise may increase erosion that will lead to remobilization of buried wood and modify patterns of wood distribution within channels, lakes, and at the coast, although we observed that sites with abundant buried wood tend to form vegetated, erosionally resistant points. Previous research on LW in rivers of the Puget Lowlands has shown that large logjams assist in stabilizing portions of the floodplain where wood deposits create "hardpoints" at which new vegetation establishes (Collins et al., 2012). This local armoring effect is likely also present in the MRD, although this effect is likely to lessen as a warming climate will shorten residence times of wood in the system. In addition to climate change, anthropogenic impacts on Arctic deltas such as dam construction will also disrupt wood supply, altering the carbon storage potential of these systems. A lower wood supply may also negatively impact the stability of deltaic and coastal banks, mobilizing aged organic matter from the landscape.

4.3. Is the Mackenzie Unique?

Brief mentions of Arctic driftwood accumulating in Siberia's Lena River delta and initiating the formation of islands along the Siberian coast (Zukov, 1941), as well as descriptions of driftcretions near the Slave River delta and along the shores of the Great Slave Lake (Kramer & Wohl, 2015), indicate that the wood accumulations described here for the Mackenzie delta are not unique. However, accumulations have not been systematically mapped and this is the first attempt to do so. The large area and lack of human alteration of riverine process and form in the Mackenzie Delta facilitate retention of substantial quantities of driftwood that might be flushed to the oceans through other, smaller deltas. No systematic measurements exist of riverine wood fluxes or driftwood accumulations along extensive regions of the world's coasts (Wohl & Iskin, 2021), leaving a remarkable gap in our understanding of global carbon dynamics. The Mackenzie Delta stores the world's largest documented wood deposits, making the delta a carbon storage hotspot in the landscape. The Mackenzie River is also famous for wood output to the ocean, functioning as a major Arctic wood pump that provides insight into how other Arctic rivers might have functioned prior to extensive timber harvest (Hellmann et al., 2015). We find high variability in the spatial and temporal dynamics of these LW carbon pools that ultimately influence the transport and storage of globally significant amounts of organic carbon over thousands of years. We anticipate that further investigation using historical records and terrestrial and nearshore stratigraphy will reveal other substantial historical locations of riverine wood transport to the oceans.

Acknowledgments

Geospatial support for this work provided by the Polar Geospatial Center under NSF-OPP awards 1043681 and 1559691. This work utilized resources from the University of Colorado Boulder Research Computing Group, which is supported by the National Science Foundation (awards ACI-1532235 and ACI-1532236), the University of Colorado Boulder, and Colorado State University. Field work, acquired imagery, and radiocarbon analyses were funded via a NSF-NERC grant to RGH (NE/R017530/1) and to EW (NSF 1740382). Samples were collected under Scientific Research License 16106 issued by the Aurora Research Institute. The satellite imagery analyzed in this work is copyright Maxar 2021. The authors would like to thank Tom Bianchi and another anonymous reviewer for their comments that helped to improve this manuscript and one anonymous reviewer for their suggestions on a previous version of this manuscript.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

The radiocarbon data is accessible via the NERC EDS Environmental Information Center (https://doi.org/10.5285/19be1a45-c457-40af-a582-395257d7a3b0). All field information (images, survey data) including the supporting information datasets is accessible via the Arctic Data Center repository (https://doi.org/10.18739/A2RV0D23X; Sendrowski et al., 2022).

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