LETTER

Fire reduces riverine DOC concentration draining a watershed and alters post-fire DOC recovery patterns

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Abstract

The loading of dissolved organic carbon (DOC) from soils to inland waters and ultimate transport to the ocean is a critical flux pathway in the terrestrial biosphere carbon cycle. Fires can significantly affect this flux through biogeochemical processes related to oxidation and mobilization of DOC in the soil. Therefore, in order to accurately estimate and model terrestrial carbon storage and export to the marine environment, we need to better understand the effects of fire on DOC flux. In this analysis, we compiled available observational data sets from seven watersheds across the conterminous United States generally spanning the years 1999–2019. We used these data sets to examine the effects of fire on riverine DOC concentration draining a watershed to study both the immediate impacts and the post-fire recovery patterns. Our results suggest that these fires result in an immediate decrease in riverine DOC concentration draining the watershed by 26 ± 15%, and the time required for DOC concentrations to recover to pre-fire levels was estimated to be, on average, approximately 9 months. During recovery, DOC concentration was 24 ± 11% lower than the long-term average for the watershed. In addition, the larger the proportion of the watershed that burned, the greater the concentration decrease and the longer the time period for post-fire recovery.

1. Introduction

Dissolved organic carbon (DOC) can be formed by the incomplete decomposition of soil organic carbon, exuded by plants, or introduced by the washout of organic compounds in throughfall [1, 2]. The total flux of DOC—from soils to inland waters via surface runoff, export from the watershed, and ultimate delivery to the ocean—is an important component of the global carbon cycle [3, 4]. Recent studies estimate that an average of 255 TgC yr\(^{-1}\) DOC is transported to oceans globally [5–7]. These large estimated quantities suggest that the lateral transport of carbon plays an important role in the overall dynamics of the terrestrial portion of the Earth’s carbon cycle [8–10] and therefore both its inter-annual dynamics and long-term trend need to be better characterized in order to reconcile the difference between top-down and bottom-up estimates of carbon exchange [11]. Current studies suggest that many environmental factors interact to control the process of DOC flux, including weather, atmospheric sulfur and nitrogen deposition, and land cover [12–15]. Disturbances such as fire and harvesting also affect the DOC loading from soils to inland waters [16, 17]. Thus, incorporating environmental factors, atmospheric depositions, and disturbances in modeling and estimates of inter-annual dynamics and long-term trends of DOC flux is required.

As one important disturbance in terrestrial ecosystems, fires directly release carbon to the atmosphere through biomass burning as well as create the potential long-term sink of pyrogenic carbon by incomplete combustion [18, 19]. Existing estimates of the terrestrial biosphere carbon budget have typically focused on quantifying the direct vertical release of carbon or the potential long-term carbon sink caused by fires [20, 21]; however, the impacts of fires on the lateral flux of DOC are rarely included in these estimates. Fires can influence the export of
DOC from watersheds by dramatically reducing the DOC content in the soil through the burning of soil organic carbon, as well as by affecting lateral transport of DOC through soil by altering soil properties (e.g. soil pH, sorption ability) [17, 22]. Schindler et al. [23] found that the riverine DOC concentration declined following a wildfire in boreal regions, presumably due to decreasing DOC loading from soils to streams. Santos et al. [24] concluded that the low-severity fire can increase the riverine DOC concentrations 1 year after the fire. Larouche et al. [25] suggested that potentially due to rapid ecosystem recovery after fire, riverine DOC concentrations in arctic headwater streams did not contain significantly decreasing. In tropical peatlands, Sazawa et al. [26] indicated that the leaching of DOC concentration from the burned soils was lower than that from the unburned soils. In addition, Uzun et al. [27] concluded that compared to unburned litter samples, the leaching capacity of DOC from burned litter samples decreased by 40 ± 20%. Therefore, including fire effects in models and carbon budget estimates is necessary to improve our understanding and quantification of the spatial and temporal dynamics of the terrestrial–aquatic DOC flux.

In existing estimates of DOC flux, including empirical models [e.g. 6, 7] and process-based terrestrial biosphere models [e.g. 28–30], fire effects on DOC flux are rarely or weakly represented. Climate change projections such as an extended fire season length, decreasing precipitation and increasing aridity due to earlier snowmelt and rising temperatures [31] lead to an increase in lightning caused fire ignitions as well as in burned area and fire severity [32–34]. Through intentional or accidental ignitions, human activities also contribute to the increasing fire frequency and severity [35]. Therefore, a quantitative understanding of fire effects on the DOC flux is necessary to improve current estimates and predictions of terrestrial ecosystem carbon dynamics. In this study, we compiled DOC concentration measurements together with an empirical model and fire records of seven watersheds from the conterminous United States to examine fire effects on the riverine DOC concentration and the post-fire recovery pattern draining a watershed. We hypothesize that fires reduce the riverine DOC concentration draining a watershed, and that the reduction levels are related to the proportion of the burned area in the watershed.

2. Data and methods

2.1. Dissolved organic carbon (DOC) data

The data sets used to estimate the pre- and post-fire daily riverine DOC concentration draining a watershed were obtained from long-term observational data provided by the US Geological Survey (USGS) National Water Information System (NWIS; https://waterdata.usgs.gov/nwis/). From these, we compiled the measured DOC concentration and the date of each measurement along with daily water discharge over the available time period, which differed for each watershed but overall included the years 1999–2017. Seven watersheds (tables 1, S1 (available online at stacks.iop.org/ERL/16/024022/mmedia)) were selected based on their data sets satisfying all of four criteria: (a) the riverine DOC concentration draining a watershed should have more than 100 measurements of DOC concentration in different days; (b) the DOC concentration was recorded at least ten times during the post-fire year; (c) all of the daily discharge measurements were recorded during the time period analyzed; (d) a watershed should have at least one fire that burned at least 5% of this watershed during the analysis period. The first, second and third criteria were required to realize the estimate of daily riverine DOC concentration draining a watershed (see section 2.3). The fourth criterion was required to observe major fire effects on DOC flux, because smaller fires are not likely to detectably change the DOC flux in this database. The boundary of each selected watershed was obtained from the USGS Watershed Boundary Dataset (WBD) from the National Geospatial Program (NGP; www.usgs.gov/core-science-systems/ngp/national-hydrography). The seven watersheds selected varied greatly in size and ranged from 151 km² (North Sylvamore) to 2927 km² (Suwannee Watershed).

2.2. Fire records and land cover data

Fire records including the start date, fire size, fire boundary map, and burn severity were obtained from the Monitoring Trends in Burn Severity (MTBS, www.mtbs.gov/) (table 1), which provides the extent of individual fires across all lands of the United States from 1984 to present. The burn severity layers categorized each fire into one of six types: not available (because of clouds, cloud shadows, and data gaps), increased greenness (increased post-fire vegetation response), unburned to low, low, moderate, and high [36]. Because burn severity maps are raster maps with a spatial resolution of 30 × 30 m, the average value of all pixels within an individual fire was calculated to represent the burn severity of this fire (table 1). Note that pixels having no burn severity information (value = 1) was not included in this calculation.

The most recent National Land Cover Database 2016 (NLCD2016) [37], provided by the Multi-Resolution Land Characteristics (MRLC) consortium (www.mrlc.gov/), was used to characterize each watershed. For this analysis, we aggregated the 16 classes of the original NLCD2016 into eight land cover types: developed area, open water, agriculture land, herbaceous, shrub, forest, woody wetland, and herbaceous wetland (figure S1, table S2). The land cover type for woody wetlands included the areas where forest or shrub accounts for greater than 20% of
2.3. DOC concentration estimation

The limited number of directly measured riverine DOC concentrations draining the watershed precluded the analysis of pre- and post-fire trajectories of DOC concentrations. Therefore, reconstructing the daily DOC concentration using available records was required to analyze the fire effects on riverine DOC concentrations draining the watershed. Hirsch et al. [38] proposed the Weighted Regressions on Times, Discharges, and Season (WRTDS) model (equation (1)) to estimate daily riverine DOC concentration draining a watershed with direct measurements:

$$\ln(C_{WF}) = \xi + \alpha \ln(Q) + \beta_f + \gamma \sin(2\pi t_m) + \delta \cos(2\pi t_s) + \varepsilon$$

where $C_{WF}$ is the daily DOC concentration (mg l$^{-1}$) estimated by the original WRTDS model, $Q$ is the daily discharge (l), $t_f$ is the order of the year (i.e. 1, 2, 3 ... $T$), $t_m$ is the order of month (i.e. 1, 2, 3 ... 12), and $t_s$ is the order of the day (i.e. 1, 2, 3 ... 365 or 366). Parameters $\xi$, $\alpha$, $\beta$, $\gamma$, and $\delta$ are fitted coefficients, and $\varepsilon$ is the unexplained variation.

But effects of fire on the riverine DOC draining a watershed is not included in WRTDS model. Because fire size, fire severity and time since the last fire can affect the DOC concentration exported from a watershed [24], it is necessary to incorporate these effects on estimating the DOC concentration in this model. Therefore, we added these three fire effects as variables in the WRTDS model and named the new model WRTDS-fire (equation (2)). We then applied the updated WRTDS-fire model to estimate the daily riverine DOC concentration draining a watershed:

$$\ln(C_{WF}) = \ln(C_{WF}) + \theta f + \rho fs + \mu e^{-\text{tolf}}$$

where $C_{WF}$ is the daily DOC concentration (mg l$^{-1}$) estimated by the WRTDS-fire model adding to equation (1), $f$ as the size of the fire (percentage of the total area), $fs$ as the class of burn severity (2, 3 ... 6), and $t_{olf}$ as the time since last fire (i.e. 1, 2, 3 ... n days). Parameters $\theta$ and $\mu$ are fitted coefficients. The process to organize the fire data was described in text S1.

To estimate fitted coefficients, a bootstrapping estimation method was applied. First, in a watershed, 20 DOC records were randomly selected from its records pool and the rest of the records were used to estimate these fitted coefficients. Secondly, this process was repeated 100 times and each fitted coefficient was the mean value of its 100 estimates.

Table 1. Descriptions of the seven watersheds analyzed in this study, including the time periods of recorded riverine dissolved organic carbon (DOC) concentration draining a watershed, and the burn information for each fire record. (Burn severity: not available = 1, increased greenness (increased post-fire vegetation response) = 2, unburned to low = 3, low = 4, moderate = 5, and high = 6).

| Watershed | DOC Drainage ($\text{km}^2$) | Time period | Sample size | Year | Month | Day | Size ($\text{km}^2$) | Size (%) | Burn severity |
|-----------|-----------------------------|-------------|-------------|------|-------|----|-------------------|----------|---------------|
| Merced    | 469                         | 2000–2017   | 511         | 2001 | 7     | 10 | 37.1              | 8        | 5             |
| Mogollon  | 231                         | 2012–2019   | 146         | 2012 | 4     | 9  | 178.1             | 77       | 5             |
| North Sylamore | 151               | 1981–2019   | 163         | 2007 | 3     | 18 | 13.7              | 9        | 3             |
| Santa Ana | 2169                        | 1971–2019   | 415         | 2016 | 3     | 2  | 15.4              | 10       | 3             |
| Sopchoppy | 264                         | 2013–2019   | 143         | 2013 | 4     | 8  | 79.5              | 30       | 5             |
| Suwannee  | 2927                        | 1971–2019   | 492         | 2011 | 5     | 30 | 183.7             | 6        | 3             |
| West Clear | 624                         | 1996–2019   | 230         | 2017 | 4     | 6  | 136.2             | 5        | 4             |

vegetated area and the soil or substrate is periodically saturated with or covered with water [37]. Fires analyzed in this study mostly occurred in the forest and woody wetland areas (figure S2).
between recorded and estimated DOC concentration for a given day, and a two-sample t-test was performed to test for differences within each watershed. Since the p-value can be controlled by the sample size \([40, 41]\), we calculated the p-value with a bootstrapping method. We conducted this bootstrapping procedure in four steps: first, we randomly selected 30 daily pairs of recorded and estimated DOC concentrations from each watershed’s time-series data set; second, we calculated a p-value from the 30 paired recorded and estimated data sets for each watershed; third, the first and second steps were repeated 100 times to obtain 100 p-values for each watershed; and fourth, the mean of these 100 p-values was calculated to represent the p-value of that watershed:

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AD = \frac{\text{abs}(C_e - C_r) \times 100}{C_r} \quad (3)
\]

where AD is the absolute difference (%), \(C_r\) is the estimated DOC concentration, \(C_e\) is the recorded DOC concentration in the same day. A lower AD indicates a higher similarity.

### 2.4. Analysis methods
We analyzed the time-series DOC concentration data for each watershed with the timing of fire events to determine length of the time that was required for the post-fire DOC concentration to recover to long-term average levels (figure 1). For a watershed, the long-term average level of daily DOC concentration was the average DOC concentration calculated from estimates in a given day of every year during the analyzed time period. To decide the length of recovery time, we used the stable status decision method AD in the measured mean presented by Wei and Larsen [39], updated to incorporate the moving average to overcome impacts of random fluctuations and re-named the moving average mean stable decision method. A time step of 30 d (approximately 1 month) was used in this study; after a fire, the moving average DOC concentration of every 30 d was calculated. The beginning of the recovery period was measured from the day of a fire to the day when the moving average DOC concentration: (a) exceeded the lower boundary of the 90% confidence interval of the long-term average level of daily DOC concentration, and (b) was greater than the lower threshold of the subsequent 29 d (30 d or approximately 1 month in total higher than the lower boundary of the 90% confidence interval).

We examined the relationships between fire properties (i.e. fire severity and burned area) and the post-fire changes to DOC concentration (i.e. immediate change and average change over the recovery period). The instant change is the change in DOC concentration exported from the watershed in the first day of the fire event. The average change in DOC concentration is the average change of daily DOC concentration during the recovery time period.

### 3. Results

#### 3.1. Model performance
Comparisons of the DOC concentration estimates using the WRTDS-fire model showed good agreement with the recorded measurements across the seven watersheds analyzed in this study (figure 2, table 2). The mean of the recorded average daily DOC concentrations in rivers draining these seven watersheds was 11.44 ± 2.36 mg l\(^{-1}\), similar to the 11.62 ± 1.72 mg l\(^{-1}\) of the estimated concentrations (table 2). The recorded concentrations ranged from 1.23 ± 0.16 mg l\(^{-1}\) in the North Sylamore watershed to 36.61 ± 7.63 mg l\(^{-1}\) in Sopchoppy. Comparatively, the estimated concentrations ranged from 1.29 ± 0.07 mg l\(^{-1}\) to 38.22 ± 6.37 mg l\(^{-1}\) between the same two watersheds. The mean AD (see section 2.3) across all watersheds was 3.6 ± 1.2%, ranging from 0.6 ± 0.2% in the Merced watershed to 8.8 ± 2.3% in West Clear watershed. The \(R^2\) between estimated DOC concentrations and records had a minimum value of 0.48 of Santa Ana watershed and a maximum value of 0.88 of Mogollon watershed with a mean of 0.69 (figure S3). In addition, the p-value ranged from 0.29 (Suwannee watershed) to 0.61 (Santa Ana watershed) with a mean of 0.39, giving us high confidence that the estimated DOC concentrations were not significantly different from the recorded measurements overall or in any of the individual watersheds.

#### 3.2. Fire effects and post-fire recovery patterns
The summarized results suggest that the length of recovery time required for daily riverine DOC concentration draining a watershed to return to its long-term average level ranged from 219 d in the Merced watershed (fire date: 15 August 2014, fire size: 5% of this watershed) to 402 d in Mogollon (fire date: 9 May 2012, fire size: 77% of this watershed) to 267 ± 55 d of all fires in the seven watersheds (table 3). The average of the immediate post-fire change in DOC concentration was −26 ± 15%, ranging from −75% in the Mogollon watershed (fire date: 9 May 2012, fire size: 77% of this watershed) to −8% in West Clear (fire date: 21 June 1996, fire size: 5% of this watershed). During the recovery time period, the average change of daily DOC concentration was −24 ± 11%, which ranged from −33 ± 15% in the Mogollon watershed (fire date: 9 May 2012, fire size: 77% of this watershed) to −17 ± 10% in Sopchoppy (fire date: 24 February 2017, fire size: 9% of this watershed).

#### 3.3. Relationships
Our analysis of post-fire changes in riverine DOC concentration draining a watershed (short-term change and the average change during the recovery period) and the properties of the fire (fire severity, burned area) revealed several strong correlations among these factors (figure 3). The results show that...
the length of recovery time was correlated on a logarithmic scale with burned area within the watershed (figure 3(a), $R^2 = 0.82$, $p$-value < 0.00), where greater burned areas were coincident with longer recovery times. The immediate change in DOC concentration was linearly correlated with the burned area (figure 3(b), $R^2 = 0.82$, $p$-value < 0.00), and increasing burned area was coincident with a decrease in DOC concentration. The immediate change in DOC concentration was linearly correlated with the length of recovery time (figure 3(c) and $R^2 = 0.60$, $p$-value < 0.00), and increasing recovery was coincident with a decrease in DOC concentration.

**4. Discussion**

As hypothesized, our results suggest that fires can significantly and rapidly reduce riverine DOC concentrations draining a watershed, and that these reduced concentrations can persist over a post-fire recovery period of time that is related to the proportion of the fire. There are several ways in which burning can cause significant soil organic carbon loss through both combustion in the fire itself as well as with the reduction in DOC produced post-fire as a result of the modified post-burn environment (notably the loss of above and belowground plant cover) [42]. First, during the fire, a large quantity of soil organic carbon including DOC is directly combusted and released to the atmosphere as gas emissions [17]. Second, high temperatures at the soil surface during the fire can thermochemically convert soil organic carbon to more recalcitrant pyrogenic carbon [43, 44]. The result is that, post-fire, a certain amount of soil organic carbon becomes protected from physical degradation and microbial decomposition [45]. This means that there will be less labile organic carbon in the soil available for incomplete decomposition, thus reducing a key pathway for DOC production. Third, vegetation mortality from the fire will result in a reduction in the amount and quality of DOC exuded by roots in the post-fire environment [46]. Fourth, the complete or partial removal of tree canopies during or after the fire will reduce the DOC production...
introduced by the washout of organic compounds in throughfall [47]. Fifth, fires can affect soil microbial abundance and enzyme activities [48, 49]. The direct combustion and heat transfer to soils during fires can lead to heat-induced mortality of soil microbes and thus reduce rates of organic carbon decomposition.
Table 3. The average daily DOC concentration (mg l\(^{-1}\)), recovery time (days), immediate post-fire change in daily DOC concentration (%), and average change in daily DOC concentration during the recovery time period (%).

| Watershed    | Fire size (%) | Recovery time (days) | Immediate change (%) | Average change (%) |
|--------------|---------------|----------------------|----------------------|--------------------|
| Merced       | 7.91          | 239                  | -10                  | -31 ± 12           |
| Mogollon     | 4.82          | 219                  | -17                  | -25 ± 11           |
|             | 77.01         | 402                  | -75                  | -33 ± 15           |
|             | 9.1           | 224                  | -29                  | -29 ± 14           |
|             | 7.04          | 319                  | -20                  | -31 ± 10           |
| North Sylamore | 9.17       | —                   | -32                  | —                  |
|             | 10.23         | 259                  | -34                  | -26 ± 8            |
| Santa Ana    | 5.62          | 220                  | -14                  | -29 ± 13           |
|             | 30.09         | —                   | -46                  | —                  |
|             | 8.02          | —                   | -21                  | —                  |
| Sopchappy    | 7.21          | 254                  | -16                  | -21 ± 11           |
|             | 8.52          | 259                  | -9                   | -17 ± 10           |
|             | 20.19         | 309                  | -31                  | -19 ± 8            |
|             | 8.23          | —                   | -25                  | —                  |
| Suwannee     | 28.99         | 322                  | -43                  | -21 ± 9            |
|             | 6.28          | 209                  | -20                  | -18 ± 11           |
|             | 3.58          | 196                  | -11                  | -19 ± 9            |
|             | 5.14          | 207                  | -8                   | -28 ± 12           |
| West Clear   | 19.77         | 322                  | -29                  | -19 ± 8            |
|             | 8.48          | 246                  | -23                  | -29 ± 11           |
| Mean         | 14.36         | 262                  | -26                  | -24 ± 11           |

Figure 3. The relationship between length of recovery time of riverine DOC concentration draining a watershed and burned area within the watershed (a), the relationship between the immediate, post-fire change in DOC concentration and burned area (b), and the relationship between post-fire change in DOC concentration and the length of recovery time (c).

and subsequent DOC production [50]. At the same time, fires alter soil physical and chemical properties such as hydrophobicity and nutrient concentrations, and these changes may in turn have negative consequences for microbial activity and thus DOC production in the soil [51].

In addition to the consequences for DOC production, fires can also affect the riverine DOC concentration draining a watershed by physically changing the hydrological conditions for DOC movement from soils to inland waters [52]. By removing vegetation, fires alter soil properties that may induce the water repellency and reduce the soil water retention time, which have been reported to decrease DOC concentration in surface runoff [53, 54].

Our analysis estimates that, on average, it takes a relative short time period of 9 months after a fire for the riverine DOC concentration draining the watershed to recover to its long-term average level, ranging from 196 to 402 d in this study. Fires can increase the soil pH [54] and thus decrease its DOC sorption ability. With less sorption more DOC will be released to inland waters, which would accelerate the post-fire recovery of DOC concentration to the long-term average level. Fire-produced charcoal may reduce the sorption of phenolic compounds, which can otherwise inhibit microbial activity [55], thus promoting post-fire soil decomposition and DOC production [56]. Likewise, the deposition of ash following fires can increase soil pH and stimulate microbial activity, which accelerates the turnover of the remaining organic matter and produces DOC in the soil [51]. After fires, vegetation regeneration provides biomass inputs to the soil organic carbon
pool for decomposition and DOC production [57]. In addition, through vegetation removal by burning, fires may accelerate soil erosion [58] and increase DOC loading from soils to inland waters [59]. Parro et al [60] indicated that root biomass in burned areas was essentially the same as unburned forest and Turco et al [61] found that after 2 years, the post-fire forest soil organic carbon was not significantly lower than the pre-fire level. Our results suggest that fire can significantly and rapidly reduce riverine DOC concentrations draining the watershed; however, the mechanisms described above induced by the fire can accelerate the recovery of DOC concentrations to pre-fire levels, although reflecting a novel suite of dynamic equilibria for DOC production in the watershed. The size of these fires ranged from 5% to 77% with an average of 13% with no complete watershed fires that could partially explain the reason for the relatively short recovery period.

In aquatic ecosystems, a portion of the DOC loading from soils to inland waters will be decayed and released to the atmosphere as outgassing and a portion will be buried as sediment, while the remaining will be transported out of the watershed [62]. However, the extent of open water in these seven watersheds is no more than 1% (table S2), so the biogeochemical processes related to DOC flux in open waters are not included in this study.

Burn severity provided by the MTBS data is mapped using the Normalized Burn Ratio, which is calculated from pre- and post-fire Landsat imagery and categorized into six classes (i.e. not available, increased greenness, unburned to low, low, moderate, and high) [36]. This burn severity characterization relates principally to visible changes in living and non-living biomass, fire products (scorch, char, ash), and soil exposure, and thus it represents effects of fire on vegetation biomass, particularly in the upper strata [36]. Our results suggest that there are no obvious relationships between the changes of DOC concentration (i.e. short-term change and average change during the recovery time period) exported from watersheds and the MTBS measures of burn severity. This is potentially related to the limited number of categories used to classify the burn severity, and the limitations of this method in representing the fire effects on soil carbon loss. In these seven analyzed watersheds, North Sylamore and Suwannee had 6% and 4% overlayed burned area (percentage of the total watershed area), respectively (figure S2). Therefore, the limited number of suitable watersheds and small proportion of overlayed burned area constrain the analysis of the difference in DOC flux patterns affected by spatially independent and dependent fires. Another limitation of this study is that, since the measurements of pre- and post-fire soil pH, soil microbial abundance and enzyme activities as well as soil carbon content are not available, the major source of this decreasing riverine DOC concentration draining the watershed is not identified in this study.

5. Conclusion

Our results suggest that fires can significantly reduce the riverine DOC concentration draining a watershed immediately and over a post-fire recovery period. To better characterize the short-term carbon budget and the inter-annual dynamics of carbon fluxes at regional watershed scale, the fire effects on DOC export from watersheds should be included. The increasing size of fire within a watershed is coincident with decreasing riverine DOC concentration draining that watershed. Based on this analysis, we estimated that it takes approximately 9 months for the riverine DOC concentration draining a watershed to recover to its long-term average level. In addition, if excluding the fire effects, the riverine DOC concentration draining a watershed could be overestimated, and its temporal dynamics not adequately characterized. Our results also suggest that empirical and process-based models (e.g. TEM6 [28], TRIPLEX-HYDRA [5]) using riverine DOC concentration draining a watershed to estimate the DOC export from a given region, which typically do not account for fire effects, will be (a) unable to characterize the temporal dynamics of DOC concentration in rivers, and (b) likely to overestimate the total amount exported from watersheds with burned area during the post-fire year.

Data availability statement

The data that support the findings of this study are openly available at the following URL/DOI: https://doi.org/10.7910/DVN/2N9YN2. The WRTDS-fire model can be accessed in GitHub (https://github.com/xinyuanwylb19/WRTDS-fire-Model.git).

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