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# Dissolved organic carbon concentrations and fluxes correlate with land use and catchment characteristics in a semi-arid drainage basin of Iran

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ABSTRACT

Dissolved organic carbon (DOC) affects biogeochemical processes in natural waters but factors affecting surface water DOC concentrations are rarely explored. Here, we related the spatial and temporal variations in DOC concentration at 10 sub-catchment outlets of the Zidasht catchment (Iran) to morphological and soil characteristics of the catchment. The DOC concentrations ranged between 1.8 and 35 mg $L^{-1}$ with a mean value of 11.9 mg $L^{-1}$. DOC concentrations were more affected by season than by location, with autumn means being twice as high as summer means, while DOC fluxes (kg $ha^{-1}$ $y^{-1}$) were only affected by location. The DOC concentrations increased with the proportion of agricultural land in the sub-catchment and with increasing soil organic carbon or nitrogen content or soil enzyme activities (urease, alkaline phosphatase, β-glucosidase, and dehydrogenase). Forward stepwise general regression models revealed that surface water DOC concentration and flux were explained by season (classification effect) and increased with increasing soil organic carbon content of the sub-catchment and discharge per unit area. This suggests that DOC concentrations and fluxes are controlled by land use and characteristics of the catchment.



## 1. Introduction

Dissolved organic carbon (DOC) in surface water originates from inputs of terrestrial organic carbon, from in-stream production or from human waste discharges. DOC has a significant role in the cycling of elements; it provides a major source of energy for biological activity and has a role in the transport and availability of nutrient and pollutants (Fellman et al., 2008). In addition, DOC fluxes from catchments are significant compared to the net ecosystem carbon balances of terrestrial systems (Brunet et al., 2009).

A wide variety of physical and chemical catchment attributes have been used as predictors of DOC in surface water. Such predictors range from chemical soil properties such as the soil carbon to nitrogen ratio (C:N; Aitkenhead-Peterson et al., 2005; Aitkenhead and McDowell, 2000), watershed land use (Aitkenhead-Peterson et al., 2009; Winn et al., 2009) to topography (Ågren et al., 2007; Aitkenhead et al., 1999; Ogawa et al., 2006; Winn et al., 2009), climate (Mattsson et al., 2009) and hydrology (Wagner et al., 2008). The statistical association of DOC in rivers with either sediment load or particulate organic C is rather weak at a regional scale (Findlay et al., 1991; Gao et al., 2000). This suggests that sediment run-off is not a prime driving factor affecting DOC and that the DOC is not directly originating from in-stream solubilization of particulate organic matter.

Thus, the controls on DOC mobilization and export are clearly complex. Soil biological processes are likely important for the solubilization of organic matter as they catalyze the hydrolysis of soil organic matter. Soil microbial activities are closely related to soil enzyme activities (Miralles et al., 2007). Soil enzyme activity may be also be related to DOC release since hydrolyzing enzymes release organic moieties from crop residues and soil organic matter. Consequently, soil enzyme activities could be complementary controlling factors to currently existing biophysical catchment characteristics to model DOC concentration in surface waters. Schimel and Weintraub (2003) reported that it is possible that exoenzyme control of DOC generation may be one mechanism driving the relationship between DOC leaching and soil C:N ratio as reported by Aitkenhead and McDowell (2000). It is therefore worthwhile to investigate if, and to what extent, enzyme activity can be used as a proxy for DOC release. As far as we are aware, this hypothesis has not yet been tested. The objective of this study is to analyze soil biochemical and catchment characteristics that explain spatial and temporal variation in DOC concentration at river outlets in a catchment of Iran.

## 2. Materials and methods

### 2.1. Study area

The study was conducted in the Zidasht catchment (36°05′35″ to 36°11′46″N and 50°37′46″ to 50°44′56″E) which is part of the

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Taleghan Drainage Basin, in the Southern Alborz Mountains, 90 km Northwest of Tehran, Iran (Fig. 1). The drainage area of the Zidasht catchment is 62.3 $km^2$ including 790 ha (12.7% of total area) crop fields (wheat), 336 ha (5.4% of total area) of orchards (walnut, almond and cherry trees), 19 ha (0.3% of total area) of residential rural area, and 5085 ha (81.6% of total area) natural rangelands (grass, forb and shrub e.g. *Astragalus* sp., *Agropyron* spp., *Bromus* sp.). The Zidasht catchment has a mountainous topography, with a minimum and maximum elevation 1690 m and 3038 m above the sea level, respectively. The average slope gradient is 20%. The soils within the catchment are mainly Typic Xerorthents, Lithic Xerorthents, Typic Xerochrepts, and Typic Calcixerepts. Long-term (1975–2005) mean annual precipitation (P) in the study area is ca. 460 mm and is strongly dependent on elevation (E). This relationship can be described by the following regression equation:

$$P = 0.444E–277.9, R^2 = 0.81 \quad (1)$$

Mean annual, mean monthly minimum and mean monthly maximum temperatures are 9.7 °C, 2.4 °C and 17 °C, respectively. Fig. 1 shows 10 sub-catchments selected as study areas, land-use map, monitoring sites for water samples and distribution of soil samples.

### 2.2. Water samples

Water samples were collected in two replicates at 10 stream monitoring sites in the spring (20–21 May), summer (25–26 August), autumn (5–7 November) and winter (20–22 February) 2007–2008 (Fig. 1). All water samples were collected in an acid-washed glass bottle that was pre-rinsed with sample water. Once collected, the samples were immediately stored in a field refrigerator on ice and transported to the laboratory where they were stored in the refrigerator at 4 °C until DOC measurement. Stream discharges at the monitoring points were manually measured at the time of sampling by means of the velocity-area method (Gordon et al., 2004). This method requires measurement of the area of a stream cross section and the average stream velocity. Discharge is then calculated as $Q = V \times S$: where Q is discharge ($m^3\ s^{-1}$ that finally converted to $L\ s^{-1}$), V is average velocity ($m\ s^{-1}$) and S is cross-sectional area of the water ($m^2$). Area was calculated from cross-section measurements. Flow velocity was measured with a hand-made float and corrected based on floating ratio. The discharge per unit area ($Q_{area}$) is the ratio of discharge and area of the sub-catchment.

### 2.3. Water DOC measurement

Water samples were filtered through a pre-combusted (500 °C, 6 h) MN GF-6 glass-fiber filter (pore size: 0.45 μm) using an acid-washed glass syringe and a stainless steel filter unit. The samples were transported on ice to the Iranian National Center of Oceanography for DOC analyses. The samples were acidified to $pH < 3$ with hydrochloric acid and stirred for 5 minutes to remove inorganic carbon and the filtrates were analyzed for DOC. The DOC was measured using high-temperature combustion on a total carbon analyzer (ANATOC™ Series II, Australia) calibrated with benzoic acid.

### 2.4. Soil collection and characterization

A total of 54 soil samples were taken in August 2008 representing the different land cover types across the 10 sub-catchments. Sampling sites were selected so that similar landform (slope, aspect and elevation) or uniform topographic positions were selected in each of the 10 sub-catchments. The number of soil samples that was taken as well as their location was based on the statistical weighting of the area-percentage of each land use (agricultural and rangelands) in each sub-catchment. The number of soil samples and other relevant information for each sub-catchment in the study area are shown in Table 1. The percentage of agricultural land use in the sub-catchments varied from 0% (in sub-catchments 9 and 10) to 54.1% (in sub-catchment 7). The sub-catchments 4 and 9 have the minimum and maximum mean slope 4.5% and 58.2%, respectively.

The samples were collected from the upper soil layer (0–20 cm) using a trowel. For each sample 5 sub-samples were collected over an area of approximately 100 $m^2$ which were mixed into a single

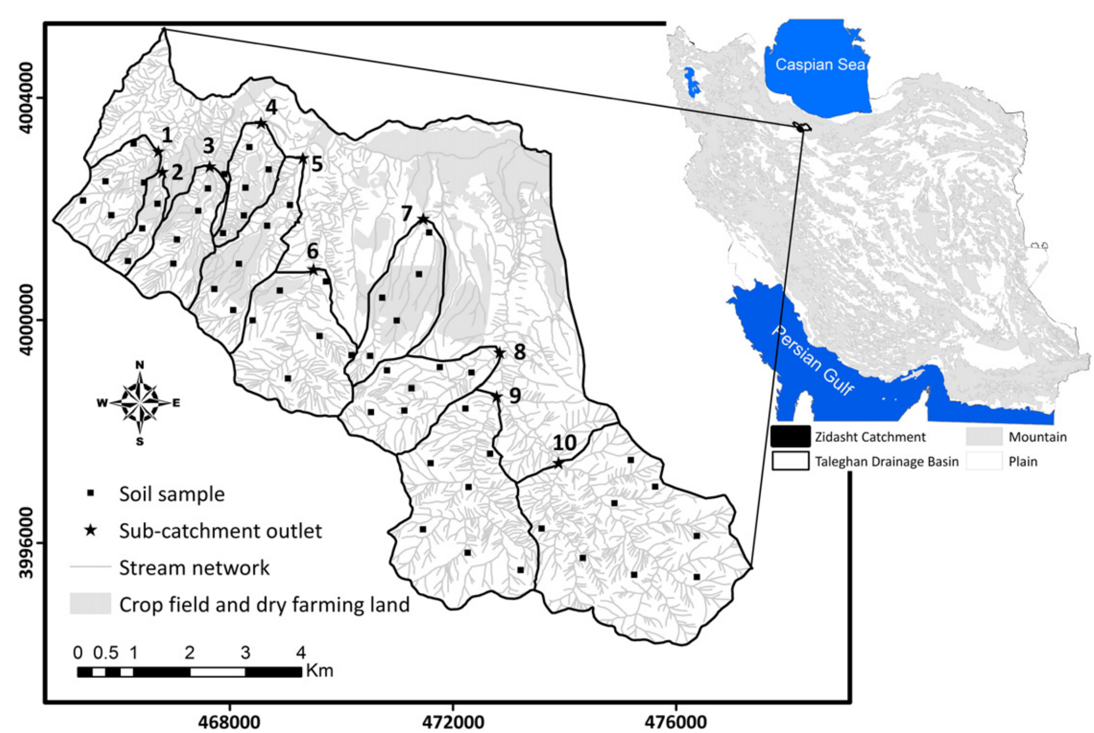


**Fig. 1.** Location map of the Zidasht catchment and sampling sites in sub-catchment. The universal transverse Mercator (UTM) coordinate system was used as the coordinate system.