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Temporal variations of sediment source from a reservoir catchment in the black soil region, Northeast China

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ABSTRACT

An understanding of long term temporal variations in sediment sources from a catchment is necessary to identify the major sources of sediment for effectively implementing soil conservation measures. For this purpose, a sediment column from Qixin reservoir and 410 samples from the three potential sediment sources were collected and radionuclides, soil organic carbon (SOC) and soil texture were analyzed. The relative contributions from different sources were determined using a simple mixing model with ^{137}Cs and $^{210}Pb_{ex}$. The mean contribution of sediment from cultivated lands to the sediment deposit was 50.87%, varying from 12.22% to 80.84%. Uncultivated lands contributed a mean of 5.22% ranging from 0.01% to 21.49% and gully/channel banks contributed 43.91% ranging from 15.15% to 86.91%. The relative contributions from the cultivated and uncultivated sediment sources to the reservoir deposit were significantly ($P = 0.01$) correlated with radioactivities, SOC and D_{50}. The temporal variations of sediment source were determined by yearly rainfall amount and rainfall erosivity. The results indicate that conservation practices should be prioritized in the cultivated lands and gullies/channels and temporal preparation strategies for heavy rainstorms should be considered using physical soil erosion models combined with field investigation.

1. Introduction

Sediment source is essential in establishing a catchment sediment budget, developing models, and designing and implementing soil conservation strategies (Gruszowski et al., 2003; Haddadchi et al., 2014). Thus, interest in sediment source identified by fingerprinting properties has increased in recent decades, and more and more work on sediment sources have been conducted in many regions over the world, such as in the UK (Gruszowski et al., 2003), the USA (Wallbrink et al., 1998; Lamba et al., 2015), Brazil (Franz et al., 2014), Tunisia (Slimane et al., 2013), Korea (Kim et al., 2013) and Chinese Loess Plateau (Zhang et al., 1989; Yang and Xu, 2010) and Southwestern region (Zhang et al., 2004). However, seldom study on this issue has been conducted in the black soil region of Northeastern China, where soil has been experiencing severe erosion, resulting from the easy erodibility of black soil, harsh climatic conditions and extensive human activity.

Fingerprinting technique used to identify sediment sources is based on linking the physical or geochemical properties of the potential sediment sources to sediment at the catchment outlet (Haddadchi et al., 2013; Lamba et al., 2015). Different types of fingerprinting properties such as metals (e.g., Blake et al., 2012), stable isotopes (e.g., McKinley et al., 2013), mineral magnetic properties (Walling et al., 1999) and fallout radionuclides (e.g., Huisman et al., 2013) have been used, among which fallout radionuclides ^{137}Cs and $^{210}Pb_{ex}$ are commonly used in a variety of geomorphic settings (e.g., Peart and Walling, 1986; Wallbrink et al., 1998; Gruszowski et al., 2003).

Sediment sources and sinks are highly variable in time. The climate changes may result in temporal changes of precipitation, temperature and land cover, which may induce different erosion and sediment transport processes (Kim et al., 2013). For example, due to changing discharge and suspended sediment, the sediment contributions from surface/subsurface were different during a flood event (Yang and Xu, 2010; Gourdin et al., 2014). Monthly changes of sediment contributions from woodland, channel bank, pasture and cultivated lands were also observed by Walling (2005). Seasonally, bare soils on upland area in spring are more prone to erosion, while stream banks are easily eroded in winter during freeze–thaw activity (Gellis and Noe, 2013). Similarly, catchment sediment output also changes throughout a year. Accumulated sediment in reservoirs contains long term erosion information and has been used worldwide to study variations of sediment yield

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(Nahm et al., 2010; Lamba et al., 2015). However, few work were conducted with sedimentation information to identify long term changes of sediment source.

Therefore, the aim of this study is to analyze the annual dynamics of potential sediment sources with radionuclides properties using the sedimentation information from Qixin reservoir in the typical black soil region, Northeastern China.

2. Materials and method

2.1. Study area

The 9.9 km^2 reservoir-controlled Qixin catchment (E106°21′, N47°25′) is situated in the southeastern Baiquan County, Heilongjiang Province, China (Fig. 1). The reservoir was constructed in 1967 with storage capacity of 103 $\times 10^4$ m^3 for irrigation. The irrigation period extends from May to August. Although the water level is lowered during irritation period, the sediments are rarely exposed. The overall morphology of the catchment is characterized by long slopes and gentle gradient of ca. 4%. The elevation of the catchment ranges from 200 to 270 m.

The climate is semihumid and continental with a long and cold winter. Annual mean temperature is 1.28 °C, and mean January and July temperatures are −22.6 °C and 37.8 °C, respectively. Mean annual precipitation is 475 mm. The major land uses in the catchment are crops (77%), grassland (12%), scrub (7%), forest (2%), and residential (2%) (Fig. 1). The main crops are soybean (*Glycine max* (L.) Merr.) and corn (*Zea mays* L.).

The dominant soil association is classified as silty clay loam Mollisols and Phaeozem. The parent materials are Quaternary lacustrine and fluvial sand beds or loess sediments that lie below these soils (Wei et al., 2008).

2.2. Soil sampling

To maintain the dam, the reservoir was drained during 2011–2013. A pit was dug at its central part, a site usually used for collecting sediment core in a reservoir or other type of water body in literatures (e.g., Townsend and Seen, 2012; Lin et al., 2012), in September, 2013, and a 120 cm sedimentary column was collected along the edge of the pit. The column was locally subsampled at 2.4-cm interval using an iron ring. The ring is 2.4-cm high with a 10.5 cm diameter.

Each individual sample from the potential sediment source areas was a composite of 10 subsamples collected within an approximate 10-m radius. For the (un) cultivated lands, soil samples were collected from 0–2 cm topsoils with a soil scraper. In the gully/ channel banks, the freshly-eroded scars were selected as the sampling points. In total, 180 and 90 samples were collected from cultivated and uncultivated lands, and 140 samples were collected from gully/channel areas where bank erosion and failure were active.

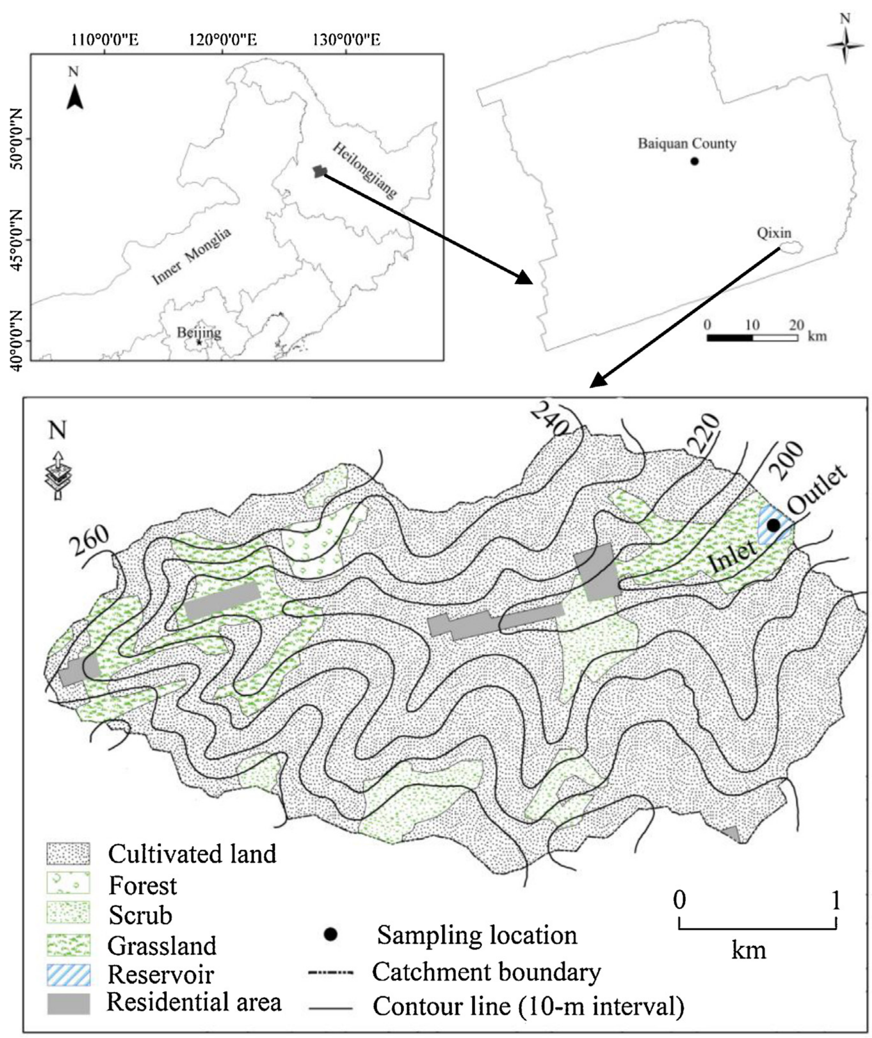

Fig. 1. Land use characteristics in the dam-controlled Qixin catchment and the sampling location within the reservoir.