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Effect of land use types on stream water quality under seasonal variation and topographic characteristics in the Wei River basin, China

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ABSTRACT

The effect of topographic characteristics of land uses on stream water quality must be addressed for a better understanding of the complex relationship between land use and stream water quality. In this study, Geographic Information System (GIS) and Pearson correlation analysis were used to determine whether there were relationship between land use types and stream water quality at the sub-basin scale in the Wei River basin, China, during the dry and rainy seasons in 2012. Temporal variation of these relations was observed, indicating that the relationships between water quality variables and different land uses were weaker in rainy seasons than that in dry seasons. Compared with other land uses, agriculture and urban lands had a stronger relationship with water quality variables in both rainy and dry seasons. Topographic characteristics of land use were employed to further analyze these relationships. The results showed that seasonal variation also occurred in the complex relationship, and land uses in steeper slopes generally had a stronger influence on stream water quality than those in flatter ones. For the riparian zone of each sampling site, the slope coefficients were weaker than those at the sub-basin scale. Land use type near stream water was generally a better indicator for the effectiveness of water quality. These results suggest that the slope and proximity should be taken into account for better land use management.

1. Introduction

Although the significant impact of land use on stream water quality has been well documented (Johnson and Gage, 1997; Allen, 2004; Hurley and Mazumder, 2013; Bu et al., 2014; Ye et al., 2014), further study on the complex association should be considered as much as possible, particularly on how the association varies temporally and with different topographical characteristics of land use.

As part of the climatic influence on surface water quality (Clark et al., 1996; Hunter, 2003), the importance of the temporal scale on the corresponding relationship should be noted. Dominant factors of the temporal scale, such as precipitation, temperature and agricultural activities, vary among seasons, and given their role on flow convergence process and contaminant inputs into water bodies, researchers have suggested that it is imperative to consider seasonal variation when studying the impact of land use on river water quality (Johnson et al., 1997). Ye (2014) indicated that while non-point source pollution was predominant in rainy seasons, agricultural and forested land showed stronger association with water chemistry. Bu (2014) employed statistical and spatial analyses to investigate the relationship between land use patterns and river water quality in the Taizi River basin, China, during both dry and rainy seasons, and found that during dry seasons, point source pollution was predominant, but in the rainy season water quality showed mixed pollution from both point and non-point sources.

Many studies have addressed the general relationship between land use patterns and water quality; however, a full understanding of the correlation has not been achieved because land use types as a whole are actually mutual reflections of multiple factors, such as geomorphic characteristics and anthropogenic activities.

In addition, the topographic characteristics (e.g., averaged slope) of catchments were frequently used to obtain an improved understanding of the association between land use and water quality. Christopher et al. (2010) distinguished the effect of different proximities of far-field and near-field land use on water quality and indicated that the near-field, 200 m buffer on each side of the stream showed significant influences on river health, while the far-field

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buffer did not. Wang (2013) performed an analysis on the correlation between water quality and land use types by incorporating the average slope of each sub-basin, but the average slope at the sub-basin level was still of a relatively coarse resolution, while other factors affecting water quality at the sub-basin scale were still hidden. Generally, previous studies mainly focused on single geomorphic factors, and few studies have made attempts to further study the geomorphic characteristics at the class level, which is of a finer resolution, to obtain an improved understanding of the dynamic complexity of relationship between land use patterns and water quality.

The objectives of this study were (1) to compare the influence of land use on stream water quality in rainy seasons to that in dry seasons in an attempt to determine which season has a more significant impact on the stream water quality in the Wei River basin, and (2) to incorporate the topographic characteristics of each land use type at the sub-basin scale to detect how the slope of each type affected the association. The influence of the slope on this type of association could add a new dimension of understanding to the environmental factors encompassing a watershed drainage area.

2. Materials and methods description

2.1. Study area description

Wei River, the largest tributary of the Yellow River, originates north of the Niaoshu Mountain at 3485 m in Gansu Province, China, and flows across 818 km with 134.3×10^4 km^2 of drainage area. The study basin consists of three catchments—the Wei River catchment (W, representing 46.1% of the total area), the Jing River catchment (J, representing 33.85% of the total area) and the Beiluo River catchment (L, representing 20.1% of the total area)—and each catchment has special characteristics (Fig. 1). The Wei River catchment is the most developed area of the three catchments, which means that it has a large amount of industry and a high percentage of sealed surfaces; in the Jing River catchment and the Beiluo River catchment, oil extractions, which strongly affect the surrounding environment, occur (Kang et al., 2008). In addition, this river provides numerous ecosystem services, including a source of water for domestic, industrial and agricultural purposes in the Guanzhong Plain, thereby playing an important role for the development of economics and society in Western China.

Land use information was obtained from the Resource and Environmental Sciences Data Center of CAS (Chinese Academy of Science). Data was provided in a 30 m × 30 m resolution and included information from six land use categories (as shown in Fig. 2): (1) agriculture land, including paddy fields and dry land; (2) forestland, including shrub land and sparse woodlot; (3) grassland, including different coverage types; (4) water body, including rivers, wetlands and sandy beaches; (5) urban land, including industrial and residential areas; and (6) barren land, including gravel, bare ground and bare rocks.

A digital elevation model (DEM) at a 30 m × 30 m resolution was used to delineate the basin area and to extract topographic characteristics, such as the average slope of each land use type at each sub-basin. The Wei River basin was delineated into 44 sub-basins based on the locations of sampling sites. Each sampling site was selected as the outlet point for a discrete sub-basin. Therefore, the effect of land use composition and its topographic characteristics (e.g., average slope and distance) on water quality was analyzed at the sub-basin level.

In addition, to further study the impact of topographic characteristics on the relationship between land use type and water quality, four categories of slope were extracted from the DEM, including category I (0–5°), category II (5–15°), category III (15–30°) and category IV (30–68°), in both sub-basin and riparian scales. These four types of slope were then taken into account after Pearson's correlation analysis on the relationship between land use and water quality.

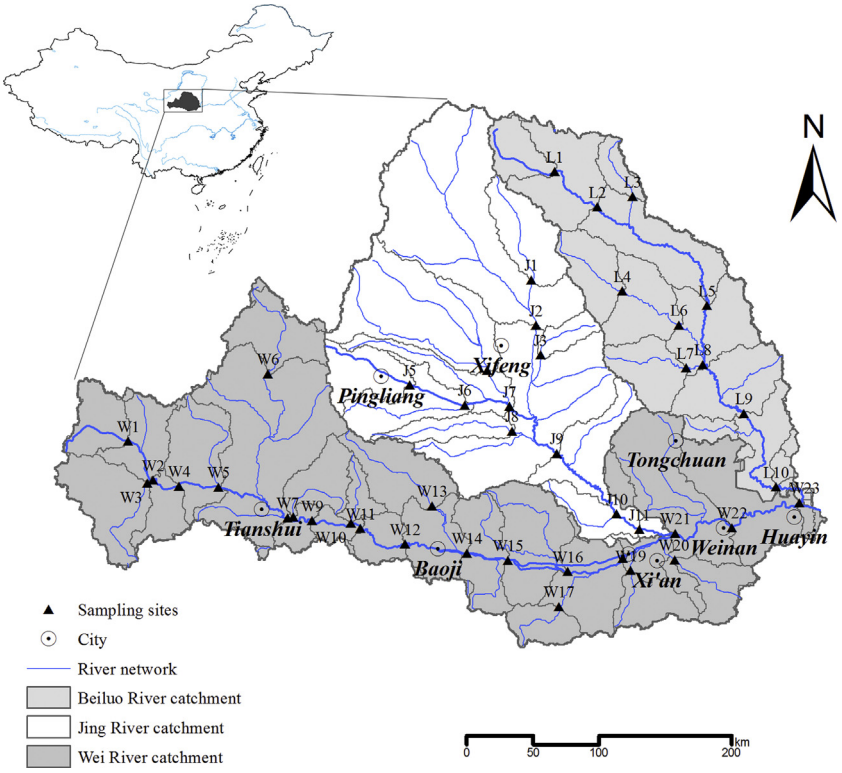

Fig. 1. Study area and distribution of sampling sites. The black solid triangles represent sites in the Wei River basin. The circles represent the main cities in the basin. (Base map is derived from DEM by extracting borders of the basin in ArcGIS software).