Sediment Accumulation on Roads in Yamashina Ward, Kyoto City: Equation construction and spatial differences

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Introduction

Surface sediments typically undergo a cyclical process of accumulation during dry seasons and erosion during rainy seasons, migrating into stormwater drainage systems with rainfall. Consequently, urban surface sediments constitute the primary source of sediment within these systems. Sediment accumulation can reduce the drainage capacity of sewer systems, thereby increasing the risk of urban flooding and jeopardizing the safety of urban environments. Simulating sediment migration across entire urban areas aids in predicting sediment accumulation points within drainage systems and assessing the risk of blockages in urban drainage infrastructure.

However, prior to conducting rainfall simulations, accurately estimating the supply of surface sediment is critically important. Typically, sediment on urban roads migrates and gradually accumulates due to transportation and wind transport. Previous studies have demonstrated significant differences in sediment levels between densely built-up areas and sparsely developed zones, with higher sediment concentrations generally observed in densely populated and high-traffic areas. Consequently, sediment content on urban roads may exhibit spatial variations across larger urban regions. Furthermore, the temporal accumulation process of sediment may also vary due to local regional characteristics. For urban areas, comprehensive areal sampling is impractical; typically, only partial point sampling can be conducted, with results extrapolated to the entire area using interpolation methods. However, considering the impact of local variations, it is necessary to identify suitable methods to incorporate local characteristics into the interpolation process for spatial sediment estimation, thereby evaluating regional sediment loads.

Methodology

Figure 1 illustrates the study boundaries and sampling sites. Sampling occurred between rainfall events, with vacuum-assisted collection conducted over a 14-day period at each site. Sediment samples totaling at least 3 m² were gathered from each sampling point. After drying, the road sediment mass at each site was measured, and sediment accumulation equations were developed based on temporal variations.

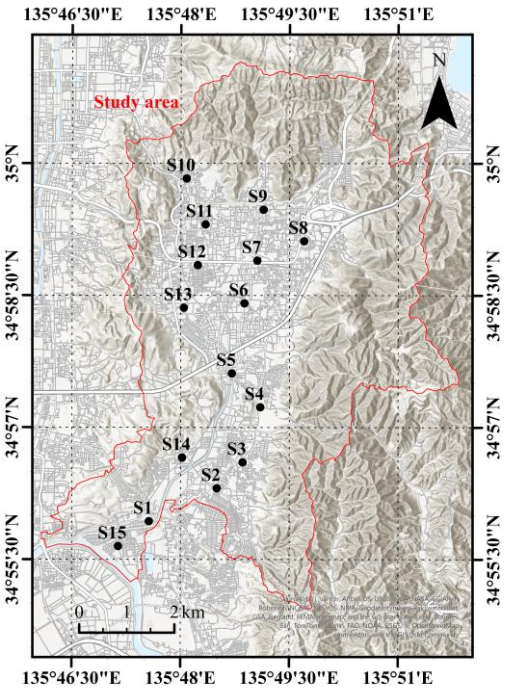

Fig. 1. Study area and sampling location

Subsequently, by comparing the differences in equation parameters, we discuss the potential local variations that may influence parameter changes.

Finally, the spatial distribution of sediment volume calculated using the following two spatial interpolation methods is compared with the average accumulation formula.

$$M_s = \sum_{i=1}^{3} \left(\frac{M_i \times (1/d_i^2)}{\sum_{j=1}^{3} 1/d_j^2}\right) \quad \text{(Inverse Distance Weighting method)}$$

$$M_s = \sum_{i=1}^{15} (W_i \emptyset(\|s - s_i\|)) + a_0 + \sum_{k=1}^{p} (a_k e_k(s)) \quad \text{(Radial Basis Functions-ENV method)}$$

$$\emptyset(r) = \exp\left(-\left(\frac{\sqrt{(x-x_i)^2 + (y-y_i)^2}}{c}\right)^2\right) \quad \text{(Gaussian RBF)}$$

Results and conclusion

By fitting the sediment accumulation results at each site, a fitting formula was obtained. It can be observed that the coefficients and exponents at different sites exhibit significant differences (Fig. 2).

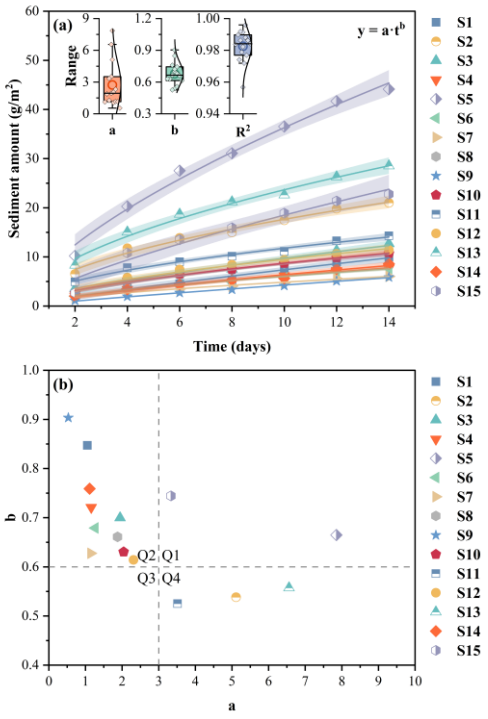

Fig. 2. Multi-point accumulation equation formula fitting results (a) and parameter distribution (b).

Based on the parameter distribution, the data can be categorized into three types: sites on major roads (Q1), sites under typical conditions (Q2), and residential area sites under sparse traffic conditions (Q4).

Different interpolation methods yield varying results, with the RBF-ENV method providing interpolation outcomes that better align with traffic impacts. However, the reliability of this method requires further validation.

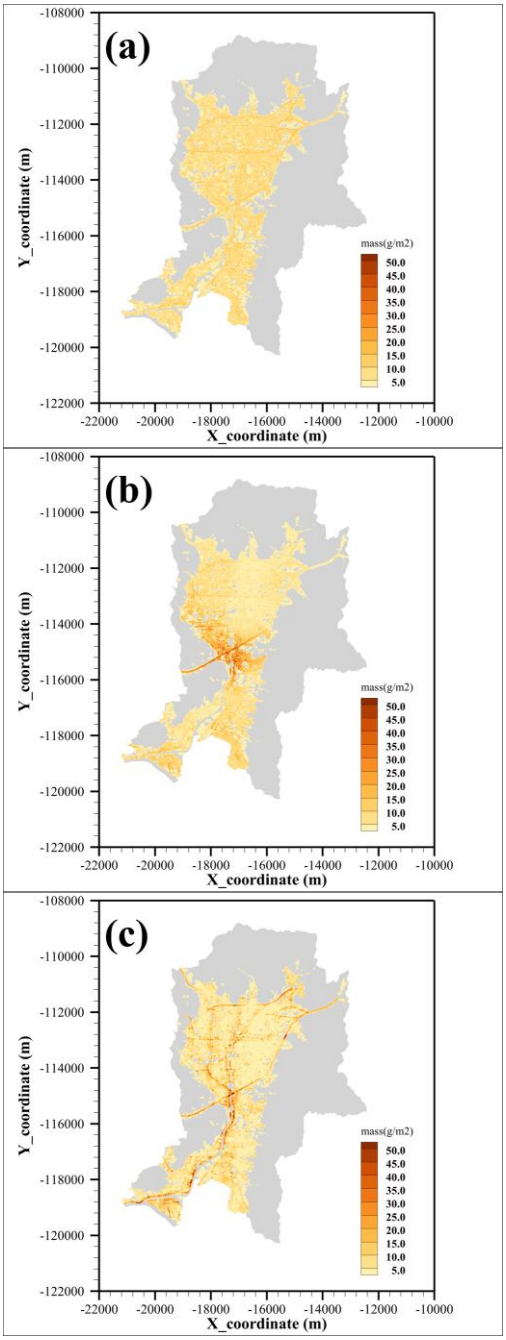

Fig. 3. Different interpolation methods: Mean (a), IDW (b), RBF-ENV (c)