A study of scale effect on specific sediment yield in the Loess Plateau, China

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Based on data from 148 hydrometric stations in the Yellow River Basin, an analysis of regional scale relationship, or the relationship between specific sediment yield and drainage basin area, has been undertaken in the study area of the Loess Plateau. For different regions, scale relationship in log-log ordinate can be fitted by two types of lines: straight and parabola, and for each line, a function was fitted using regression analysis. The different scale relationships have been explained in terms of the difference in surface material distribution and landforms. To offset the scale-induced influence, calculation has been done based on the fitted functions, in order to adjust the data of specific sediment yield to a common standard area. Based on the scaled data, a map of specific sediment yield was constructed using Kriging interpolation. For comparison, a map based on the un-scaled data of specific sediment yield was also constructed using the same method. The two maps show that the basic pattern of specific sediment yield was basically the same. The severely eroded areas \( Y_s > 10000 \, \text{t km}^{-2}\text{a}^{-1} \) were at the same locations from Hekouzhen to Longmen in the middle Yellow River Basin. However, after the adjustment to a common standard area, the very severely eroded area \( Y_s > 20000 \, \text{t km}^{-2}\text{a}^{-1} \) became much enlarged because after the adjustment, all the values of \( Y_s \) in the lower river basin in those regions became much larger than before.

Loess Plateau, erosion, scale effect, specific sediment yield.

The Loess Plateau is the key area for the research of soil erosion, and many methods have been applied to studying its erosion and sediment yield\(^{[1-5]}\). However, little research has been made concerning the scale effect. With the increase in drainage area, sediment may be deposit in the river channel or on the floodplain, due to the decrease in the steepness of hillslopes and river channels, and the interception by water conservancy projects. Also, the previously deposited sediment may be remobilized during floods. Thus, scale effect cannot be ignored in the study of sediment yield.

Walling et al.\(^{[6-8]}\) described the relationship between specific sediment yield \( (Y_s) \) and basin area \( (A) \) as a negative correlation, while Church et al.\(^{[9]}\) established a nonlinear relationship based on data from rivers in Canada, that is, with the increase of basin area \( (A) \), specific sediment yield \( (Y_s) \) increases first and then declines.

Xu et al.\(^{[10]}\) found that nonlinear relationship between specific sediment yield \( (Y_s) \) and basin area \( (A) \) also existed for rivers on the Loess Plateau at macroscopic scales.

Traditionally, the methods to map specific sediment yield follow the three steps: first, select some hydrometric stations where long-term data of specific sediment yield are available; second, determine the drainage area represented by the stations, either above a station or between two stations; third, draw the isolines of specific sediment yield using some interpolation methods. Because the involved drainage area is different from each other, the traditional methods can hold true only under the hypothesis that the variation of basin area has no effect on...
specific sediment yield, or this effect can be omitted. However, some functions have been found in the relationship between basin area and specific sediment yield, as pointed above, which demonstrated that the foregoing hypothesis is not true. Hence, when a map for specific sediment yield is to be made, scale effect must be taken into consideration, and some procedure for correction must be adopted to convert the $Y_s$ of each drainage area to a new $Y_s$ value related with a standard area. Then, the interpolation is performed to draw isolines for $Y_s$. This methodology was proposed by Church et al.\cite{11}, who have mapped the specific sediment yield for Canadian rivers. Applying the Church’s method to the rivers on the Loess Plateau, we have studied the scale effect on $Y_s$ for several subregions of the Loess Plateau and established the scale effect functions, which may be used for data conversion. On the basis of taking scale effect into consideration, a new map for $Y_s$ has been made.

1 Outlines of study area, data and method

1.1 Outline of study area

This study involves the Loess Plateau region, which is located to the west of Taihang Mountains, the east of Yaohe River, the south of Yinsan Mountains and the north of Qinling Mountains\cite{3}. Following the principles of the completeness of drainage area and the similarity of precipitation and other physico-geographical settings, and also considering the results of subregions by other researchers\cite{12–14}, the whole study area is divided into 7 subregions. As the study area is rather large, the differences in small-scale landforms in some sunregions are not excluded. The 7 subregions are listed as follows (Figure 1):

I: Subregion of west Shanxi Province along the main stem of the Yellow River, including all the tributaries of the Yellow River from Tuoketuo station to Longmen station;

II: Subregion of western bank drainage area between Hekouzhen and Longmen, including the Huangfuchuan River, Qingshui River, Gushanchuan River, Kuye River, Tuwei River, Jialu River, Wuding River, Qingjian River, Yanhe River, Fenchuan River and Shiwordian River.  

III: Subregion of Jinghe, Beiluo and Weihe Rivers, including the Beiluo River, Jinghe River, Weihe River, Qianhe River, Hengshui River and Qishui River.

IV: Subregion of the Fenhe, Yiluo and Qinhe rivers, including the Fenhe River, Qinhe River and Yiluo River and their tributaries.

V: Subregion of the Zuli and Qingshui Rivers, including Kushui River, Rujigou River, Qingshui River and Zuli River;

VI: Subregion of Inner Mongolian small rivers, including the Hademengou River, Xiliugou River, Kudulun River, Wudanggou River, Dahei River, Hadeqin River, Shuiwanggou River, Shilawu River, Shuqiangou River and Meidaigou River.

VIII: Subregion of desert, including the Hedong Desert, Mu Us Desert, Kubuqi Desert and some bordering areas.

Since no data are available for subregion VII, this subregion will not be included in this study.

1.2 Data sources

The data of mean annual flow and suspended sediment load used in this study come from hydrometric stations, which were printed and issued by the Yellow Water Conservancy for internal use (Yellow River Conservancy Commission, 1975). Since this study deals with the scale effect under natural conditions, and human activities have increased more markedly since 1970 than before, we choose the data of 1919–1970 for analysis. Data from a few stations were removed, under the following principles: (1) the time of the data is less than 5 years; (2) the river was influenced by reservoirs, which trapped sediment and reduced the specific sediment yield significantly; (3) the number of stations located in desert is too few to establish a function relationship; and (4) some stations on the lower reaches of large rivers are