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黄土高原地区土壤可蚀性及其应用研究

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摘要：通过回顾已有的成果，分析评价了我国土壤可蚀性研究的进展及存在的问题，提出我国土壤可蚀性研究中的标准小区定义。运用野外观测资料，研究计算了黄土高原地区土壤可蚀性指标值。结果表明，陕北和晋西北一带黄土可蚀性 K 值变化于 0.3～0.7 之间，并且有以陕西子洲、绥德一带为最大，以此为中心，向南、向北和向东都减少的变化趋势。

关键词：黄土；侵蚀预报；可蚀性；标准小区

Evaluation of soil erodibility on the Loess Plateau

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Abstract: Soil erosion is now universally reckoned as an ecological environment problem, which results in land degradation and a band of ecological problems such as water pollution and flood disaster, Especially in the vast northwest region of China, a key to restore ecological environment is to control soil erosion. Besides vegetation disruption, rainfall concentration, and steep farmland ect, the susceptibilities of loess to erosion substantially conduce to severe soil erosion on the loess plateau. Soil erodibility being an important index to evaluate the soil sensitivity to erosion, how to precisely study and evaluate soil erodibility is of great importance to understand soil erosion regularity, predict soil loss, and evaluate land productivity.

Since the study on the effect of soil properties on erosion began in 50s in China, an abundance of achievements about soil erodibility have been scored. But as a result of diverse perspectives and methods, a number of problems still exist. the first problem is that divers indices to evaluate soil erodibility are present. The second is that the definitions of unit plot are not uniform. The third is that algorithms used to calculate soil erodibility factor K are inconsistent. The fourth is that lacking observed data leads to little reliability of calculated results when formulae are used to predict K values. All these problems not only adversely affect the progress of the soil loss prediction research in China, but also interfere with exchange and comparison with international achievements . On the base of data from field plots. the selection of soil erodibility index and its determination method were discussed in this paper. Meanwhile, values of eodibility factor K for the soils on the loess plateau were determined and analyzed.

To date, there are mainly three different types of methods applied in soil erodibility study. The first one is based on measurement of physical and chemical properties of soil. But in can't be used to predict soil loss because how to quantitatively relate soil erodibility to soil loss was not established. The second one is based on the results from water flow experiments, which determines soil erodibility directly by measuring soil loss scoured by water. In 40s, however, Gussak noted that when this method was applied to measure

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the erodibility of two different soils, opposite orders appeared when inflow rates were different. So it is impossible for this method to exactly characterize the effect of soil properties on erosion. The third is field measurement from unit plots. Though soil erodibility factor can be directly calculated through observation data from field plots, soil erodibility was found to alter with slope gradient and even was regarded as a dynamic index being a function of natural properties, topography, precipitation, and soil conservation because improper indices were adopted in previous studies on loess erodibility in China. It is obvious that erodibility of different soils is impossible to be compared because this type of indices fails to directly reflect the influence of soil properties. We recommend that a good index used to describe soil erodibility should follow the principles of uniqueness and practicality. So-called uniqueness denotes that a type of soil corresponds to a certain eodibility value to reflect impact of soil property on erosion. Even though soil erodibility may interact with some factors such as slope, rainfall, and land use etc in measurement, it is sure that soil erodibility should not vary with these factors. Otherwise, the erodibility of soil would have myriad values and lost its meaning in soil loss prediction because the change in rainfall, landuse and topography is uncertain. So-called practicality denotes that soil erodibility must be a quantitative numeric index and be easy to be measured.

In 1963, Olson and Wischmeier proposed the practical index of soil erodibility as soil loss per rainfall erosivity index unit as measured on a unit plot, which has definite physical meaning and is convenient to measure. When measured on unit plots its values can be determined by a formula expressed as $K = \left(\sum_{e=1}^{N} Ae\right) / \left(\sum_{e=1}^{N} (EI_{30})e\right)$ where K is the soil erodibility factor, A is the rainfall-induced soil loss, EI_{30} is the rainfall erosivity factor among which E and I_{30} represent the total storm energy and the maximum 30-min intensity for a given storm respectively, and e designates the times of rainfall. Given the erodibility index values of different soils, it is feasible to predict soil loss combined with the factors such as topography and rainfall. In order to evaluate soil erodibility by consistent methods under same conditions in China, to establish to unit plot definition suitable to China is imperative.

A unit plot is thought as a benchmark used to analyze and compare the data directly measured from field plots. With the unit plot having been defined, when field data are analyzed, all data from different areas can be adjusted to the unit plot, after which the regularities can be uniformly drawn. In addition, it's only with the uniform unit plot having been defined that to consistently evaluate and compare the soil erodibility of different soils is possible. In USLE, a unit plot is 22.1m long, with a uniform lengthwise slope of 9 percent, in continuous fallow, tilled up and down the slope. This definition deviates from the cropping practive and the natural conditions of China so that it can't be generalized in China.

Though a unit plot only serves as a man-established benchmark as data are analyzed a certain number of principles should be complied with. First of all defining a unit plot is continent on particular natural conditions in addition to landform characters and land use in the investigated area. Secondly a unit plot should facilitate making the most of available data, which means making data use easy after scale and slope range of available plots are fully considered. Thirdly error from data modification should be minimum. After comprehensive consideration in practices of reclamation and cropping on steep slopes, scale and slope range of available plots and regularity of error fluctuation, we suggest that the unit plot is 20m long and 5m wide with a slope of 15 degree in continuous fallow. The plot is placed in local conventional seedbed condition and is tilled as needed to prevent marked weeds gowth in conformity with local farming system. After the erodibility of the primary soils in China is evaluated based on soil erodibility values determined from unit plots, a set of basic data will be collected serving as criteria to compare erodibility characters of soils and predict soil loss in our country.

The suitability of soil erodiblity index defined in USLE and another index to loess was examined on the base of the selected observation data from the unit plots in Ansai County, Shanxi Province. The values of soil erodibility factor K were tested against by employing the data from a group of plots of diverse gradients observed from 1985 through 1989. This group of plots, 20m long and 5m wide, with respective gradients of 5 degree, 10 degree, 15 degree, 20 degree, 25 degree and 28 degree were laid out on the same slope. These plots with the same soil type of lossent in bare fallow were plowed, tilled and weeded to keep free of vegetation perennially, similar to the measures exerted to the unit plot prescribed above. The values of soil erodibility factor K determined based on soil loss data collected from 39 times of ranifall-runoffs in 5 years and the results derived according to the definition of the index were compared. It was indicated that the K values of loess measured from the plots of different gradients were rather constant and kept invariable with the change of the plot gradients while the index altered greatly with gradients. This result revealed soil erodibility factor K used in USLE more literally respesented the effect of soil properties on erosion than the index on the loess plateau. So applying K in soil loss prediction as an index reflecting soil properties on the loess region was justified.

That the properties of loess varied markedly results in different values of soil erodibility factor on the vast loess plateau. Erodibility factor K of loess in different regions was calculated by use of the plot data collected from the chosen observation stations of Huangpuchuan, Zizhou, Lishi and Ansai etc on the loess plateau. It was shown that erodibility values of the loess ranged from 0.3 to 0.6 in American system, and from 0.04 to 0.008 in metric system. And in the investigated portions of the loess plateau in this paper, soil erodibility values distributed regularly which were high in the central region and decreased southward, northward, and eastward. The high value 0.61 appeared in the tract of Zizhou and Suide, from where soil erodibility values fall off northward to 0.531 in the watershed of Huangpuchuan, southward to 0.3278 in Ansai, and eastward to 0.4372 in the region of Lishi, Shanxi. It is primarily the regional difference of physical properties of loess that brings on the regionally various erodibility values of loess mentioned above. Soil erodibility closely relates to particle-size distribution, permeability, organic matter content and texture of soil. For loess organic matter content is generally low and texture alters slightly, so the difference of soil erodibility values is mainly influenced by the variation of particle-size distribution among which silt and clay contents are the most important factors. On the loess plateau, from the northwest to the southeast soil particles generally get finer, sand fraction decreasing. clay fraction increasing, and silt fraction firstly increasing then decreasing with the maximum appearing in the central region of Zizhou and Suide. Soil resistance to erosion gets enhanced and soil erodibility values go down with clay content increasing. With silt content increasing, soils are more apt to undergo erosion, which results in greater soil erodibility values. Therefore, the derived results tally with the fundamental change pattern of soil-particle distribution of loess in the investigated region, which further corroborates it is reasonable to apply the index of soil-particle distribution on the loess plateau. Though how to quantitatively relate soil-particle distribution to erodibility of loess in pending, these results can still be referenced to when soil loss prediction and soil conservation planning are conducted in the loess plateau.

After the results of soil erodiblity research on the loess plateau have been analyzed and the values of loess erodiblity factor have been determined based on observation data on plots, conclusions are as follows:

1. That the unit plot is 20m long and 5m wide with a slope of 15 degree in continuous fallow was suggested. The plot is placed in local conventional seedbed condition each year and is tilled as needed to prevent marked weeds growth (coverage no more than 5%) in conformity with local farming system.

2. Results calculated from observation data for unit plots indicated that compared to other indices used in soil erodibility study on the loess plateau, the index defined as soil loss per unit of rainfall erosivity index from unit plots reflects the effect of loess properties on erosion more directly and accurately.

3. Loess erodibility factor K values ranged from 0.3 to 0.7, with the maximum in Zizhou, from where K values decreased southward, northward, and eastward. The high value 0.61 appeared in the tract of Zizhou and Suide, from where soil erodibility values fell off southward to 0.3278 in Ansai, eastward to 0.4372 in the region of Lishi, Shanxi, and northward to 0.531 in the eatershed of Huangpuchuang river.

Key words: loess; erosion prediction; erodibility; unit plot

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土壤侵蚀是全球性的生态环境问题之一。土壤侵蚀持续发生的结果不仅使土壤质量不断下降,而且还会引起水体环境恶化等一系列生态问题。特别是在我国广大的西北地区,防止水土流失是重建生态环境的关键。我国西北黄土高原地区发生的严重土壤侵蚀,除了植被遭受破坏、降雨集中发生和陡坡开垦等因素之外,易于侵蚀的黄土性质是重要的原因之一。土壤可蚀性是评价土壤对侵蚀敏感程度的重要指标,如何准确地研究评价土壤可蚀性,对认识侵蚀规律,进行水土流失预报和土地生产力评价都具有重要意义。

1 问题提出

我国从 20 世纪 50 年代开始研究土壤性质对侵蚀的影响,在土壤可蚀性的研究方面也取得了不少成果。但是,由于认识问题的角度及侧重点不同,不同时期的研究,特别是在对黄土可蚀性的研究中,不同的学者采用了不同的方法、术语及评价指标。朱显谟[1]是我国最早研究土壤性质对侵蚀影响作用的学者,他将土壤抗侵蚀性能分为抗冲性和抗蚀性,并测定了土壤的膨胀系数和分散速度等性质与侵蚀的关系。后来,田积莹等[2]、史德明等[3]等通过研究土壤物理性质与侵蚀的关系,对土壤可蚀性指标进行了评价。蒋定生[4]、朱显谟[5]、李勇等[6]通过抗冲槽试验和索波列夫抗冲仪,测定了黄土的相对抗冲性指标。同时,周佩华等[7],吴普特等[8]分别尝试了用小区资料对黄土的可蚀性进行了分析计算。他们把单位径流深所引起的侵蚀模数作为土壤抗冲性强弱的指标,并认为土壤抗冲性随坡度的增加而减小、且随土地利用的不同而不同的结论。从 20 世纪 90 年代初以来,许多学者还先后对内蒙古、黑龙江、广东、福建、江西、辽宁、云南等地主要土壤的可蚀性进行了观测研究[9~16]。经过几十年的努力,虽然我国在土壤性质对侵蚀影响作用的评价方面已经取得了一些进展,但由于着眼点及采用的研究方法及不同,目前仍存在很多问题:第 1 用于评价土壤可蚀性的指标多种多样。在已有的研究中从定性到定量,使用了多个指标。指标的不统一,不仅引起了对土壤性质与侵蚀关系的认识不一,也给可蚀性指标的使用带来了极大的不便。第 2 标准小区不统一。即使所用指标相同,也会由于观测中使用的小区标准不同,其结果很难进行不同类土壤间可蚀性大小的比较。第 3 可蚀性指标值 K 的计算方法不统一。虽然有些研究中也已引用了可蚀性 K 这一指标,但计算中使用的降雨侵蚀力 R 值不同。第 4 在应用公式计算时,由于缺乏实测资料验证,计算结果可信度差。所有这些问题不仅影响了我国土壤侵蚀预报研究的进展,而且也阻碍了与国际间研究成果的交流对比。本文运用野外小区实测资料,对土壤可蚀性的研究方法、土壤可蚀性评价指标的选择确定问题进行了探讨。并对黄土高原地区的土壤可蚀性大小及其变化规律进行计算分析。

2 研究方法及资料

目前,主要有 3 种不同类型的方法被用于黄土可蚀性的研究中。第 1 种是土壤理化性质测定法。此方法尽管定性评价了土壤性质对侵蚀强度的影响作用,但没有建立土壤可蚀性与土壤侵蚀的定量关系,缺乏实用价值,不能用于侵蚀预报。第 2 种方法是水流冲刷试验法。这种方法比前一种有所进步,直接用水冲刷土壤来确定黄土可蚀性的大小,更接近降雨发生时的实际径流冲刷过程。但在 20 世纪 40 年代,古萨克就曾指出,用这种方法测定两种不同土壤的抗冲性,用不同的流量冲刷,会出现抗侵蚀性大小排序相反的试验结果。因此,它也不可能真实地反映土壤性质对侵蚀的影响作用。第 3 种方法是野外小区实测法。虽然运用小区观测资料,可以直接计算土壤可蚀性,但在我国已有的黄土可蚀性研究中,由于所选指标不妥,得

出了同一土壤的可蚀性大小随坡度的不同而变化的结论,甚至有人将土壤可蚀性理解为一个动态指标,认为它是土壤的自然性质、地形、降水及水土保持活动的函数。这种指标显然也未能直接反映出土壤性质的影响作用,也就无法进行不同地区、不同土壤间的比较。

评价土壤可蚀性的指标必须遵循唯一性原则和实用性原则。所谓唯一性是指由于土壤可蚀性是土壤特性,一种土壤只能有一个值。虽然在测定过程中,它会与坡度、降雨和土地利用等因素有一定的交互作用,但绝不应该随这些因素的变化而变化。因为坡度、降雨和土地利用可能有无穷多种,如果土壤可蚀性随它们的变化而变化的话,一种土壤的可蚀性可有无穷多个值,这也就失去了体现土壤性质差异的意义。所谓实用性是指土壤可蚀性指标必须是定量的数值指标,必须具有预报价值。同时,也要考虑测定方法的可操作性。

Olson 和 Wischmeier[17]曾于 1963 年提出了具有实用性的土壤可蚀性指标,即标准小区上单位降雨侵蚀力所引起的土壤流失量。这一指标具有明确的物理意义和方便的测定方法。在标准小区上测定时,其大小可用下式计算:

$$k = (\sum_{e=1}^{N} Ae)/(\sum_{e=1}^{N} (EI_{30})e)$$

其中,K 为土壤可蚀性因子,A 为降雨引起的土壤流失量。EI_{30}为降雨侵蚀力因子,E 降雨动能值,I_{30}为最大 30min 雨强,e 为降雨次数。有了不同土壤的可蚀性指标值后,就可以根据降雨和地形等因子值进行土壤流失量的预报。为了用统一的方法和在相同的条件下确定我国土壤的可蚀性大小,首先必须讨论研究解决我国标准小区的规范问题。

3　我国的标准小区规范及其论证

3.1　标准小区规范

所谓标准小区,指对实测资料进行分析对比时所规定的基准平台。规定了标准小区以后,在进行资料分析时,就可以把所有的资料首先订正到标准小区上来,然后再统一分析其规律性。另外,也只有在统一的标准小区条件下,才能对不同土壤的可蚀性进行统一对比评价。在美国的通用流失方程中,规定坡度为 9%,坡长为 22.13m,连续保持清耕休闲状态,且实行顺坡耕作的小区为标准小区。由于这一规定与我国农作的实际情况相去甚远,很难在我国土壤侵蚀预报中推广使用。关于适用于我国的标准小区,应该采用什么坡度及规模,曾有学者提出过坡度为 10°和 15°小区的建议[18,19],但未作系统论证。综合考虑我国陡坡开垦和耕作的习惯、现有小区的坡度范围和规模大小,以及资料订正时的误差变化规律,建议我国的标准小区最好选定 15°坡度、20m 坡长、5m 宽的清耕休闲地。小区每年按传统方法准备成苗床,并按当地习惯适时中耕,保证没有明显的杂草生长。把在这种条件下得到的土壤可蚀性值作为基本标准,对我国主要土壤的可蚀性进行测定,得到一组基础数据,作为我国土壤侵蚀性质对比及土壤流失量预报的标准数据。

3.2　规范的合理性论证

尽管标准小区只是处理资料时人为规定的基准,但必须遵循一定的原则来确定。首先,标准小区的确定必须密切结合研究区自然条件的具体实际,充分考虑土壤侵蚀发生区的地形特点及土地利用情况。其次,标准小区的条件必须能最大限度地有利于现有资料的利用。充分考虑现有小区坡度变化及规模大小,以利于现有资料的开发利用。再者,资料订正计算中的误差最小原则。确定标准小区的主要目的就是为了便于资料的对比分析,如果所确定的标准不当,在订正计算及最终的土壤流失量预报中会引起很大的误差。

我国水土流失严重的原因,除了降雨、地质地貌、地面物质组成等自然因素外,剧烈的人为活动影响具有重要的作用。与土壤侵蚀问题同样严重的美国相比,大面积的陡坡农耕地土壤侵蚀就是中国水土流失问题的具体特征。在水土流失最严重的黄土高原,坡耕地的面积约占总耕地面积的 50%,其中,在黄土丘陵区,坡耕地要占总耕地面积的 70%~90%。所以,在中国开展土壤侵蚀预报研究,必须重视陡坡地水土流失问题。表 1 是水土流失严重区典型小流域地面坡度组成情况。表中数据表明,除了黄土塬区和片沙覆盖黄土区外,陡坡地所占面积都很大。就表中所列小流域的平均而言,大于 10°的坡地面积一般要占总面积的

75.5%,大于15°的坡面占57.6%,大于25°的坡面也要占总面积的31.5%左右。在这种地形条件下,通用流失方程中提出的标准小区坡度条件明显太低,而15°正是现有坡耕地坡度范围的中间值,取其作为标准小区的坡度比较合理。

表1 黄土高原代表性小流域地面坡度组成

Table 1 Slope gradient of typed watersheds on The Loess Plateau

坡度分级(°) Class of gradient	0～10	10～15	15～25	>25	地貌类型区 Landform type
陇中天水吕二沟 Luergou in Gansu	24.4	16.2	30.9	28.5	黄土长梁丘陵区 Hilly region of long liang
陇中秦安张家沟 Zhangjiagou in Gansu	21.1	9.4	44.8	24.7	黄土长梁丘陵区 Hilly region of long liang
陕北靖边于家 Yujiawa in Shaanxi	62.2	17.4	6.3	14.1	黄土丘陵 地区 Hilly region of jian land
山西离石王家沟 Wangjiagou in Shanxi	7.98	11.7	23.4	56.92	黄土梁峁丘陵区 Hilly region of liang and mao
山西阳高大沙沟 Dashagou in Shanxi	17.72	22.5	35.4	24.38	土石丘陵区 Loessial and rocky hilly rigion
西吉黄家二岔 Huangjiaercha in Ningxia	15.1	38.5	27.8	18.6	黄土梁峁丘陵区 Hilly region of liang and mao
河曲砖窑沟 Zhuanyaogou in Shanxi	23.2	9.5	14	53.3	土石丘陵区 Loessial and rocky hilly rigion
平 均 Average	24.53	17.89	26.09	31.49	

资料来源:黄土高原区域治理与评价,科学出版社

另外,半个世纪以来,我国在全国不同地区,建立过许多野外观测小区,积累了相当丰富的观测资料。根据目前刊出的黄河流域水土保持径流泥沙观测资料以及其他地区共20几个站点的小区资料,对现有小区的坡度变化及其频率分布情况进行了统计分析,得到表2结果。表明我国小区资料的坡度范围主要变化于0°～39°之间。其中,40%左右的小区坡度落在10°～20°的范围。这一结果首先说明10°～20°的小区具有最大的广泛性,也即在各地不同立地条件下,这一坡度范围内布设的小区最多,选这一坡度级作为标准小区的坡度时,等于在标准小区上实测的资料最多。而15°也是这一坡度范围的中间坡度,说明选择坡度为15°的小区作为标准小区时,更具有资料来源上的广泛性和地形特征上的代表性。

表2 我国典型径流小区的坡度变化范围

Table 2 Slope gradient of typed field plots

坡度范围 Slope gradient	0°～5°	5°～10°	10°～15°	15°～20°	20°～25°	25°～30°	>30°
小区数目 Numbers of plots	46	70	81	74	44	53	21
百分比 % Percentage	11.8	18	20.8	19	11.3	13.6	5.4

最后,选定什么样的坡度小区来测定土壤可蚀性因子值,才会将侵蚀预报中的误差减小到最小,还需要从土壤、地形及降雨等因子间的相互作用过程加以分析。土壤侵蚀过程是指降雨过程中,雨滴和径流分散、分离及搬运土壤颗粒的过程。降雨和径流为这一过程提供能量,坡面是该作用过程发生的场所,而土壤则是作用的对象。由于坡度陡缓会通过改变径流势能和土壤颗粒自重力影响侵蚀过程中的能量变化;土壤性质的不同也会通过影响入渗来间接地影响径流动能。因此,在土壤侵蚀发生过程中,降雨径流、坡面坡度和土壤性质对土壤流失量的影响是复杂的,在它们之间存在交互作用。正是由于这种交互作用存在,在不同的坡度情况下测得的土壤可蚀性会有一定的变化。如果选择过缓或过陡的坡度作为标准小区坡度,都会在土壤流失量预报中带来较大的误差。只有取相对较为中间的坡度作为标准小区坡度时,向陡缓两个方向

应用时所引起的误差都会相对最小。因此,选择我国实际坡耕地坡度变化范围的中间值 15°作为我国土壤侵蚀研究中的标准小区坡度也符合误差最小原则。

4 结果与讨论

4.1 黄土的可蚀性指标选定 从前文的分析评价中可以看出,在目前诸多的土壤可蚀性评价指标中,具有土壤侵蚀预报价值的只有通用流失方程中定义的土壤可蚀性指标 K 和文献 7 中所规定的指标。然而,由于黄土高原地区坡面陡峻,侵蚀方式多样,以及侵蚀发生过程的独特性,哪一个指标能更好地应用于黄土高原地区,还必须进行必要的分析验证。合理的土壤可蚀性指标必须遵循唯一性原则和实用性原则。如果确定的反映土壤可蚀性大小的指标值因小区条件的变化而不同,则该指标就不能很好地反映土壤性质对侵蚀的影响作用。相反,如果所选可蚀性指标值大小不因观测小区条件的变化而变,只随土壤类别的不同而异,就表明所选指标合理。

为此,选用布设于陕西省安塞县境内的小区观测资料,对通用流失方程中定义的土壤可蚀性指标及文献 7 中所采用的指标在黄土地区的适用性进行了验证。陕西安塞位于陕北黄土高原中部,沟谷发育、地形破碎,属典型的梁峁丘陵沟壑区。年平均降水量 549.1mm,且年际变化大。年内降水主要集 中于 6~9 月份,且多以暴雨形式发生。不论从地形地貌特征,还是气候降水特点,安塞都具有一定的代表性[20]。从 20 世纪 70 年代开始,中国科学院水土保持研究所在此进行了长期的土壤侵蚀和水土保持试验研究,特别是从 20 世纪 80 年代起,系统地进行了土壤侵蚀规律观测试验。应用 1985~1989 年间的不同坡度小区观测资料来计算验证 K 值(见表 3)。这组小区布设在同一坡面,长 20m,宽 5m。坡度分别为 5°、10°、15°、20°、25°和 28°。土壤均为黄绵土,小区状况均为休闲裸露地。每年对所有小区进行统一翻松、中耕和除草,以保证常年裸露状态。小区处理类似于上述规定的标准小区要求。图 1 是根据 5a 间 39 次产流降雨的土壤流失资料,计算的黄土可蚀性 K 值和根据文献 7 中的定义计算结果的比较。图中散点的变化趋势表明,在不同坡度小区上测定的黄土 K 值相当稳定,并未因小区坡度的不同而变化。而文献 7 中定义的单位面积上单位径流深所对应的侵蚀量指标值则在不同坡度小区上有很大的变化。这就表明通用流失方程中选用的土壤可蚀性指标 K,比文献 7 中所采用的指标在黄土高原地区更真实地反映了土壤性质对侵蚀的影响作用。将其作为反映土壤性质指标,在黄土地区的侵蚀预报中应用是可行的。

表 3 安塞站不同坡度小区可蚀性指标比较

Table 3 Comparsion of the erodibility measured from different gradient plots at Ansai

坡度(°) Degree	坡长(m) Length	侵蚀量 A (t/km²) Soil loss amount	降雨侵蚀力 R (MJ·mm/(hm²·h)) Rainfall erosivity	径流深(mm) Depth of runoff	土壤可蚀性 K ((t·hm²·h)/(hm²·MJ·mm)) K factor	抗冲性指标[7] Erodibility index
5	20	7658.9	8.7E+03	225.54	4.37E-02	0.0340
10	20	22106.4	8.7E+03	260.21	4.21E-02	0.0850
15	20	38778.3	8.7E+03	263.97	4.46E-02	0.1469
20	20	51631.8	8.7E+03	276.54	4.28E-02	0.1867
25	20	69306.6	8.7E+03	276.17	4.52E-02	0.2510
28	20	70368.9	8.7E+03	277.7	4.09E-02	0.2534

4.2 黄土的可蚀性值大小及其变化 黄土高原地域辽阔,黄土的性质特点从北到南变化很大,其可蚀性大小也必然会出现差异。为此,从北到南依次选用皇甫川、子洲、离石和安塞等站的小区资料,分别计算了黄土高原不同地域的黄土可蚀性 K 值如表 4 所示。其中,皇甫川的可蚀性指标值是根据文献 9 中的资料用坡度公式订正到 15°标准小区上的计算结果,子洲站使用了团 2、团 3、团 4 和团 5 等小区的资料。离石站所用资料为 6 个不同坡度小区的观测数据。

表 4 的结果表明,黄土的可蚀性变化于 0.04~0.08 之间。同时,在本文所研究的黄土高原地区,黄土的可蚀性在地域上表现有在中部地区较大,由中部向北,向南和向东部逐渐减小的规律。黄土可蚀性最大值出现在子洲、绥德一带,黄土的可蚀性值高达 0.083。向北到黄甫川流域,黄土的可蚀性值减小为 0.069。

向南到安塞一带后，黄土的可蚀性更是减小到0.043。向东到山西离石一带，黄土的可蚀性也只有0.048。黄土的可蚀性出现这种区域差异的主要原因，可以认为主要是由黄土物理性质的区域差异决定的。土壤可蚀性的大小主要与土壤的颗粒组成、入渗特性、有机质含量，以及土壤结构有关。由于黄土的有机质含量普遍很低，结构特征也变化不大。所以，可以认为颗粒组成的变化是影响黄土可蚀性大小差异的主要因素，且可蚀性的大小主要与土壤中粉粒和粘粒含量的多少密切有关。黄土高原粒径组成变化的总趋势是从西北到东南由粗变细，沙粒含量沿该方向逐渐减少，粘粒含量则不断增加。而粉粒含量的变化是先不断增加，然后又渐渐减少，其最大值出现在位于中部地区的子洲、绥德一带[21]。土壤中粘粒含量愈高，土壤抵抗侵蚀的能力越强，可蚀性指标值越小。粉粒含量愈高，越易发生侵蚀，土壤可蚀性指标值愈大。因此，表4中的计算结果与研究区黄土粒径组成的变化基本规律一致。这也从另一方面说明了该指标在黄土高原地区的合理性。尽管关于黄土粒径组成于其可蚀性之间的定量关系还有待于进一步研究，这一结果仍可以在黄土高原地区的土壤侵蚀预报及水土保持规划中参考使用。

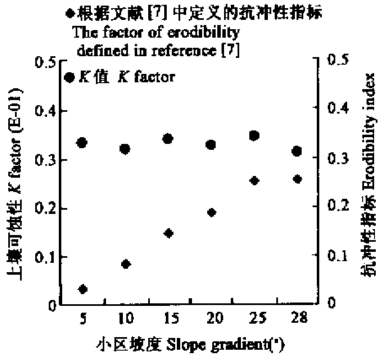

图1 不同坡度小区上测定的可蚀性指标值对比

Fig.1 Comparison of the *K* factors measured from plots with different gradient

表4 子洲、安塞、离石不同小区土壤实测 *K* 值

Table 4 Soil erodibility calculated using the data from plots at Zizhou、Ansai and Lishi station

地点 Location	坡度(°) Degree	坡长(m) Length	侵蚀量 *A* (t/km²) Soil loss	降雨侵蚀力 *R* (MJ·mm/(hm²·h)) Rainfall erosivity	土壤可蚀性 *K* (t·hm²·h/(hm²·MJ·mm)) Soil erodibility	平均 Average	备注 Note
子洲	22	40	76256.9	4.8E+03	7.29E-02		安塞、皇甫川为裸地，皇甫川的 *K* 值是据文献[9]订正到标准小区；子洲、离石为农耕地，订正到裸露地标准小区，订正系数 *C* 取0.753（祥见另文）
Zizhou	22	60	102659.6	6.7E+03	5.77E-02		
	22	20	33085.9	4.6E+03	4.8E-02	8.27E-02	
	31	20	67897	4.4E+03	7.07E-02		
安塞	5	20	7658.9	8.7E+03	4.37E-02		
Ansai	10	20	22106.4	8.7E+03	4.21E-02		
	15	20	38778.3	8.7E+03	4.46E-02		
	20	20	51631.8	8.7E+03	4.28E-02	4.32E-02	
	25	20	69306.6	8.7E+03	4.52E-02		
	28	20	70368.9	8.7E+03	4.09E-02		
离石	5	20	823.9	1.32E+03	3.09E-02		
Lishi	10	20	1388.5	1.88E+03	1.22E-02		
	15	20	6394.2	1.85E+03	3.46E-02		
	20	20	13190	1.8E+03	5.27E-02		
	25	20	12662.9	1.86E+03	3.86E-02	4.79E-02	
	30	20	18750.3	1.86E+03	4.76E-02		
皇甫川 Huangfuchuan	6	20	2669.8	1.37E+03	6.90E-02	6.90E-02	

Type of Landuse: Ansai and Huangfuchuan-bare land. Zizhou and Lishi-farm land. 子洲资料1961～1969年，摘自《黄河流域子洲径流实验站水文实验资料》；离石资料1957～1964年，摘自《山西省水土保持科学研究所径流测验资料》

5 结 论

通过分析现有黄土高原地区有关土壤可蚀性研究的成果,运用小区观测资料计算了黄土的可蚀性指标值,可以得到以下结论:

(1)建议我国在进行土壤可蚀性研究标准小区,选定 15°坡度、20m 坡长、5m 宽的清耕休闲地小区。小区每年按传统方法准备成苗床,并按当地习惯适时中耕,保证没有明显杂草生长(覆盖度不超过 5%为宜)。

(2)小区实测资料的计算结果表明,用标准小区上单位降雨侵蚀力所对应的土壤流失量多少作为土壤可蚀性指标来表示土壤性质对侵蚀的影响作用,与目前其他学者在黄土高原地区土壤可蚀性研究中所采用的指标相比,更准确、更直接地反映了黄土本身性质的差异对侵蚀的影响作用。

(3)黄土的可蚀性 K 值变化与 0.04～0.08 之间,而且有以陕西子洲一带为最大,以此为中心,向南、向北和向东都不断减少的变化趋势。在绥得、子洲一带,黄土可蚀性 K 值高达 0.083。向南到延安安塞一带,黄土可蚀性 K 值为 0.043 左右。向东到晋西北的离石,黄土的可蚀性 K 值为 0.048,向北到皇甫川沙黄土带之后,黄土的可蚀性 K 值为 0.069。

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