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ASSEMBLÉE GÉNÉRALE DE BERKELEY DE l'UGGI

19-8 — 31-8 1963

EROSION CONTINENTALE
PRÉCIPITATIONS
HYDROMÉTRIE
HUMIDITÉ DU SOL

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SECRÉTAIRE : L.J. TISON

BRAAMSTRAAT 61, (RUE DES RONCES)

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EROSION CONTINENTALE

I

ÉVALUATION DE L'ACTION DE PRATIQUES AGRICOLES ET DE CONSERVATION SUR L'ÉROSION

EVALUATION OF EFFECT OF AGRICULTURAL AND CONSERVATION PRACTICES ON EROSION

THE DETERMINATION OF SEDIMENT YIELDS FROM FLOOD WATER SAMPLING

D.A. PARSONS (**), R.P. APMANN (***) and G.H. DECKER (****)

SUMMARY

Measurements and studies of the solids content of flood waters from three watersheds of about a hundred square miles area in western New York suggest the need for additional information in order to discern even major differences in watershed erodibility with short periods of observation. These are : (1) flood flow rates at the time and place of flood water sampling; (2) flood water temperatures; (3) dryness of the soil in the sediment source areas prior to the flood; and (4) location of the major source of the flood waters, if erodibility varies over the watershed. Items (2) and (3) may be replaced by the establishment of a seasonal trend in sediment concentration values.

Comparisons of the solids concentrations in concurrent floods in the three streams showed relative changes of about 40 percent due to streambank stabilization work in Buffalo Creek, the centrally located stream. About the same changes were indicated by the analysis of the Buffalo Creek data alone when flow rates, flood water source, and season were considered.

The latter method involved the concepts : (1) the rates and amounts of runoff were unchanged during the period of observation; (2) the concentration of solids in the flood waters was related to the rate of flow, Q, such that $c = Kf(Q)$; (3) the $f(Q)$ reflects the erosiveness of the flood waters over the sediment source areas; and (4) the K is an indicator of the erodibility.

Seasonal variations in mean values for K suggested temperature and antecedent moisture effects upon erosion like those recently found by experiment at the USDA Sedimentation Laboratory. Mid-August values were about three times greater than those for January.

RÉSUMÉ

Une étude du contenu en matières solides transportées par les eaux de grandes crues dans trois bassins versants — situés dans l'ouest de l'état de New York — ayant environ trois cents milles carrés de superficie fait, ressortir la nécessité de renseignements supplémentaires, même pour discerner les différences importantes du potentiel érosif du sol lorsque les périodes d'observation sont courtes. Voici les renseignements supplémentaires dont on a besoin : (1) le débit d'eau à l'heure et à l'endroit où on a prélevé les échantillons d'eau turbide ;(2) la température de l'eau pendant la crue ; (3) la sécheresse initiale des sources de sédiments ; et (4) la connaissance géographique des régions qui amènent les plus grands volumes d'eau, ceci dans le cas où le potentiel érosif du sol n'est pas constant dans le bassin versant. On peut remplacer (2) et (3) par un facteur de correction qu'on applique à la concentration des sédiments.

Les comparaisons des concentrations de solides, lorsque les crues sont simultanées pour les trois cours d'eau, indiquent des variations relatives d'environ 40%. Ce changement est dû aux travaux de stabilisation des rives de Buffalo Creek qui est situé au milieu de ces trois bassins adjacents. L'analyse seule de Buffalo Creek indique

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le même changement approximatif si on tient compte des débits, de la source d'eau principale et de la saison.

Cette dernière méthode suppose que (1) les débits et les volumes d'eau ruisselant à la surface du bassin versant restaient invariables au cours de la période d'observation (2) la concentration des solides transportés par les eaux de crue était fonction du débit d'eau, Q, tel que $c = Kf(Q)$; (3) la fonction $f(Q)$ représente le pouvoir érosif des eaux de crue qui s'écoulent à la surface des régions qui sont, ells, sources de sédiments ; et (4) K est un chiffre indicatif du potentiel érosif du sol.

Les variations des valeurs moyennes de K selon la saison semblent indiquer que K dépend de la température et de l'humidité initiale du sol. Ces résultats ont récemment été vérifiés au «USDA Sedimentation Laboratory». Selon cette étude, les valeurs de K mesurées à la mi-août étaient trois fois plus grandes que celles du mois de janvier.

1. Introduction

A program of flood water sampling in the Buffalo River (New York) watershed was initiated in 1953 to determine the changes in sediment delivery of the streams with the application of soil erosion prevention measures. Samples were obtained over a nine-year period from Cayuga Creek at Lancaster, Cazenovia Creek at Ebenezer, and Buffalo Creek at Gardenville. These are sites of stream flow and water surface elevation measurement. Their locations within the watershed are indicated in figure 1. The drainage areas above the gaging stations are 93, 136, and 145 square miles, respectively.

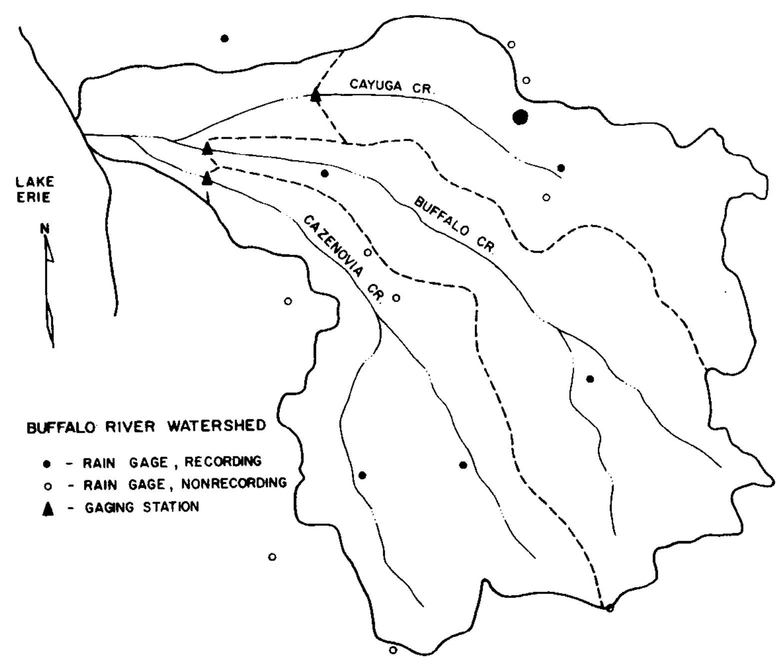

Fig. 1 — Locations of streamflow measurement, Buffalo River, New York, watershed.

According to the Buffalo Creek Watershed Report (June, 1955) by the US Soil Conservation Service, the estimated proportions of sediment carried by the river and entering Buffalo Harbor were 47 percent from upland sheet erosion and 53 percent from stream channel erosion. The planned soil conservation work was estimated to reduce the sediment discharge into the harbor by 18 percent because of upland measures and 26 percent by stream channel stabilization.

An effective and simple method of showing results of stream channel work is to make before and after observations of channel conditions. This report, however, deals with the method of runoff and sediment sampling as a means for determining the changes in downstream sediment loads.

The program involved taking depth-integrated sediment samples from flood flows with either the DH-48 or the D-49 sampler, depending upon water depth. Figure 2 illustrates schematically the procedure. The times of sampling were recorded, permitting determination of concurrent water discharge by reference to the water level gage chart and the stage-discharge curve.

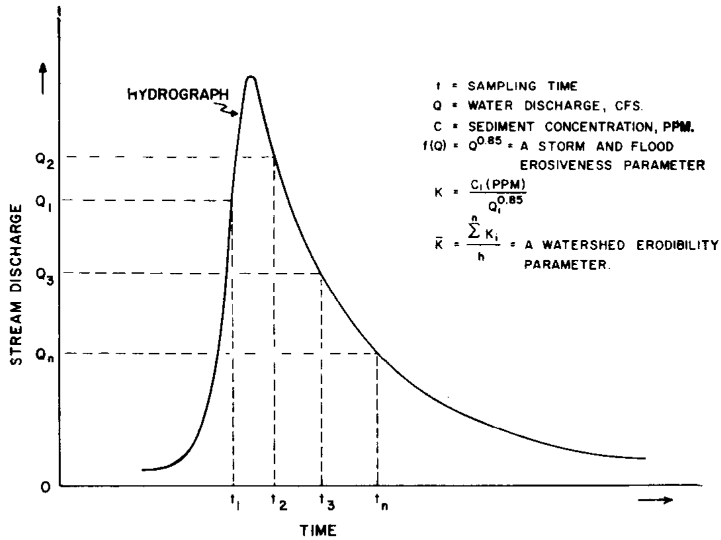

Fig. 2 — Schematic representation of flood water sampling procedure.

2. Primary data analysis

The total sediment yield in climatically similar time periods should be directly proportional to the mean concentration of solids in the runoff from the Buffalo River watershed, since there is no reason to believe that recent land use changes and erosion control measures have materially affected the rates or amounts of runoff. The relative changes in mean concentration with time should therefore be equal to the relative changes in sediment delivery. In other words, actual sediment delivery need not be computed in a comparative study. The changes in sediment concentration are indicative of the changes in sediment delivery.

Sediment concentration values for Buffalo Creek at Cardenville are shown plotted in figure 3 against the water discharge at the time of sampling as an example of the nature and variability of the data. A fractional reduction in sediment delivery, estimated to result from the erosion control works, would be impossible to positively detect in data like these, which vary severalfold in value. The first step in the attempt to reduce this dispersion was to relate the concentration to the water discharge. Thus the concentration is equal to a constant, K, times $f(Q)$, a function of discharge; or $C = Kf(Q)$. A preliminary study of the data resulted in the tentative adoption of the relation $f(Q) = Q^{0.85}$, making $C = K\,Q^{0.85}$.

Apparent rationality of this procedure is attained by consideration of the erosion process. The erosion at the source areas depends upon three things : (1) the erosiveness of the eroding agent, rainfall or runoff; (2) the erodibility of the soil; and (3) the extent of exposure of the soil to the eroding agent. The rate of streambank erosion

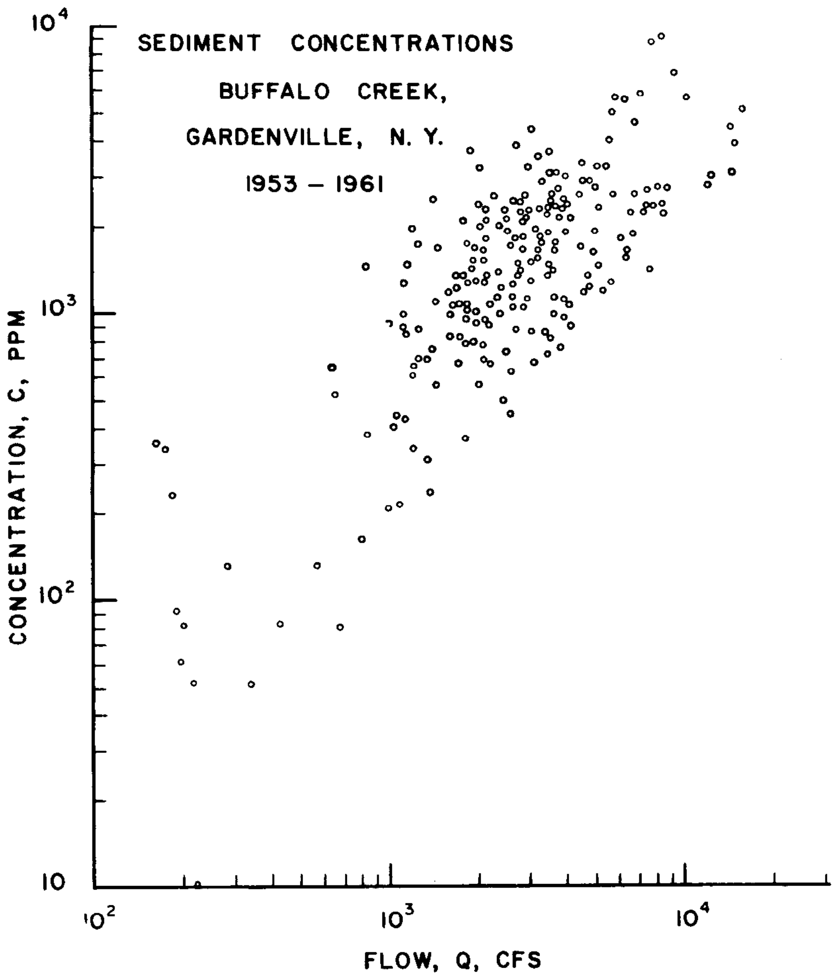

Fig. 3 — Sediment concentrations and water discharges, Buffalo Creek, Gardenville, New York. (1953-1961).

is directly dependent upon the flow rate in the channel, and sheet erosion is closely related to the rain intensity and the rate of runoff on the land surface, both of which are associated in some degree with the rate of flow in the stream channels. The intensities of the active agents in the erosion processes may, therefore, with some reservation, be expressible as, or related to, $f(Q)$. The K, then, may be considered again with some reservations to be indicative of the erodibilities and exposures of the soils in the source areas. It is referred to hereafter as watershed erodibility. It is a measure of the potential of the watershed to produce sediment at given runoff conditions. Weighted mean values of K were computed for each of the sampled floods.

3. Effects of channel stabilization

The effect of streambank stabilization work along Buffalo Creek is portrayed in figure 4. Here the mean K values for a flood are expressed in terms of the mean of these values for the concurrent floods in the bracketing Cayuga and Cazenovia Creeks. The ratios of Buffalo Creek K values to the means for Cayuga and Cazenovia

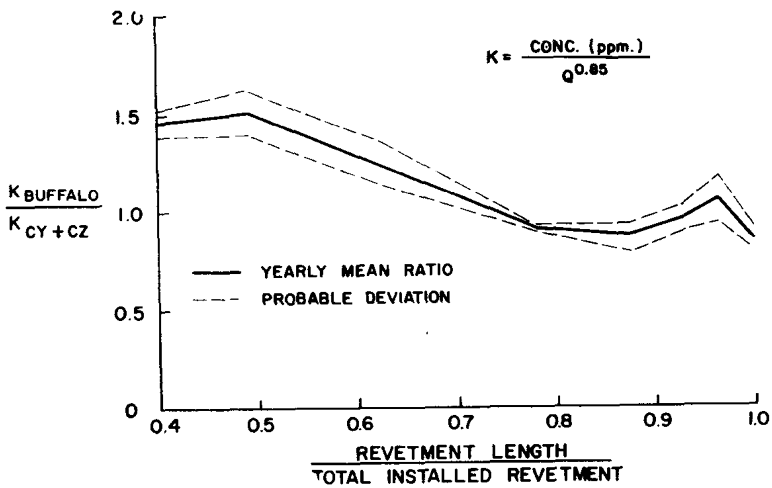

Fig. 4 — Change in relative sediment concentration with increasing channel stabilization.

Creeks were averaged by calendar years and then plotted against the proportion of completion of the Buffalo streambank protection work at the beginning of the year. Since practically no channel work was done in Cayuga Creek, and that in Cazenovia Creek was installed late in the period of comparison, the change in the ratio throughout the period should be due to Buffalo Creek channel work. Other conservation work and changes in land use were presumed to be uniformly distributed over the three subwatersheds.

The change in the ratio throughout the period is from 1.46 to 0.86, an indicated reduction in Buffalo Creek sediment delivery at Gardenville of 40 percent, due only to the channel work. This must be tempered by the knowledge that the dispersion of the data is still large and the probable deviation of a yearly value is computed to be 0.08.

4. Seasonal variations in soil erodibility

Concurrent flood water sampling of three adjacent watersheds is not usual. Measures of comparative behavior or response to treatment differences by such direct means can therefore be seldom made. Reliance upon the data from one stream to show the effects of treatments within its watershed requires a further reduction in the dispersion of the sample data. This was done, in part, by determination of the values of a seasonal variation in mean $\bar{K}$, the watershed soil erodibility factor.

Mean $\bar{K}$ values for all of the sampled floods for each of the three streams were arranged in order of time within the year regardless of the year of occurrence. Moving averages of eight of these ordered values were computed. The results are shown in figure 5. All streams exhibit the same trend in mean $\bar{K}$ value, having an average high

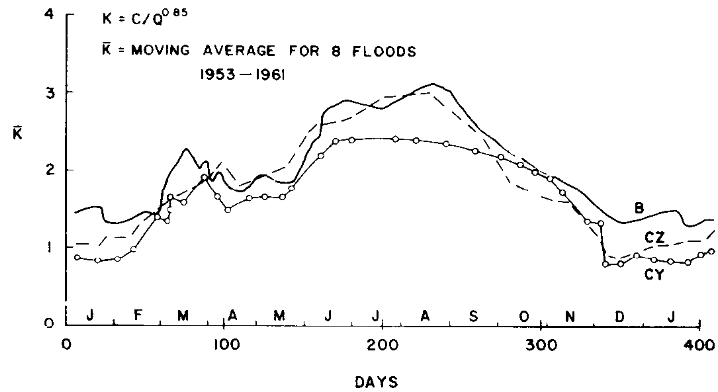

Fig. 5 — Seasonal variations in the measures of watershed erodibilities for Cayuga, Cazenovia, and Buffalo Creeks, New York.

value in August about three times the average size for January. This is in line with the marked seasonal difference found by (Miller, 1951) in studies of the San Juan River. Figure 6 shows the mean seasonal trend in K values for all these streams. These seasonal variations in watershed soil erodibility conform in direction, at least, with the temperature and antecedent moisture effect demonstrated in the laboratory by Grissinger (1962).

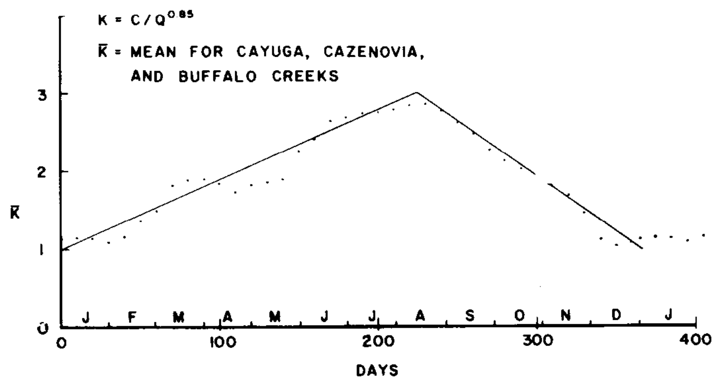

Fig. 6 — Mean seasonal variation in the measure of watershed erodibility.

In addition to this and in further general conformance with his findings on the effects of antecedent moisture and orientation of clay particles, the measure of watershed erodibility for Buffalo Creek increased on the average about twofold with increasing time between floods. This was in the absence of snowmelt.

The data for the basis of these statements are shown in figure 7. No apparent trends existed with data from snowmelt floods plotted in the same manner.

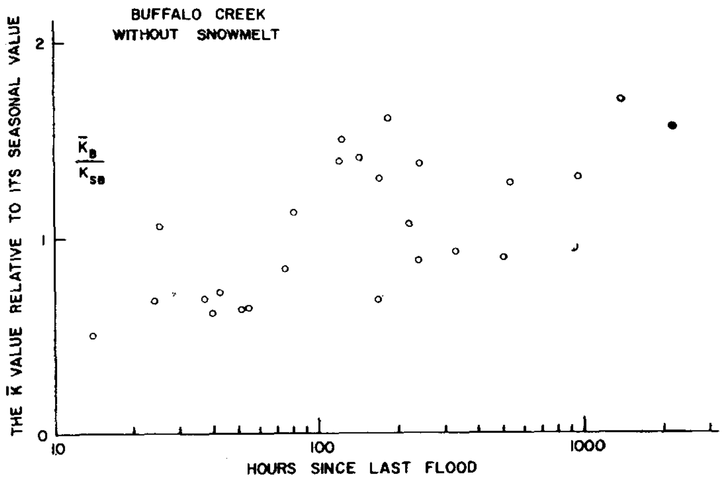

Fig. 7 — Relative values of watershed erodibility relative to the time between floods.

5. Sediment delivery vs. nature of precipitation

Table 1 gives the results of a study to show the effect of snowmelt on watershed erosion. The mean $\bar{K}$ values for floods in the five-month period — December to April, inclusive — were divided by the predetermined mean seasonal values, K_s, shown in figure 5. These ratios were then divided into two groups. The values for floods that were completely or principally derived from snowmelt were compared with those completely or principally from rainfall.

TABLE 1

Effects of snowmelt on sediment delivery

	With snowmelt		Without snowmelt	
Stream	No. of Floods	Mean $\bar{K}/K_s$	No. of Floods	Mean $\bar{K}/K_s$
Cayuga	23	0.99	11	0.98
Cazenovia	19	1.03	12	0.97
Buffalo	*24*	*0.98*	*12*	*1.08*
All	66	1.01	35	1.01

From the results shown in table 1, the conclusion is drawn that flood waters during the season December to April from either rainfall or snowmelt create the same sediment delivery for equal flow rates in the stream channels.

A very limited study of rainfall amounts in 2-, 4-, 8-, and 12-hour periods associated with flood events indicated no increase in sediment concentration of the flood waters greater than normal with increases in these long-period rainfall intensities.

6. Sediment delivery vs. source of flood waters

A summary of flood water source data for Buffalo Creek was made, using all available rainfall data. It is given in Table 2.

TABLE 2

Summary of flood water source data

Principal source of flood waters	No. of floods	Mean value of $\bar{K}/K_s$
Upper	13	1.32
Middle or General	20	0.95
Lower	11	0.78
Uncertain	11	0.98

The mean value of $\bar{K}/K_s$, watershed erodibility relative to the seasonal value, is apparently greater for floods originating in the upper part of the watershed than for the general floods, and those originating in the lower portion. Although there is a greater observable amount of erosion in the form of channel degradation in the upper reaches than lower in the watershed, it is reasonable to suspect that a part of the difference in table values for erodibility may be due to attenuation of the flood peaks due to channel storage. Localized storms of the same rarity will produce lower rates of flow at the gaging station if located in the headwaters than if in the lower part of the watershed. This is to say that the adoption of a fixed value for $f(Q)$ in the primary analysis does not allow for this deviation from the average runoff event.

7. Time trends in sediment delivery

Moving averages of sixteen consecutive values of $\bar{K}/K_s$ in time for each of the three streams are shown in figure 8. These values represent watershed erodibility adjusted for season and relative to the average for the nine-year period. Buffalo Creek values decreased from a high of 1.34 at the beginning to 0.84 at the end, representing a 37 percent reduction throughout the period. This decline in sediment delivery for Buffalo Creek was accompanied by a net rise of about 10 percent for the other creeks. The probable deviations of the break points in the curves are 0.06.

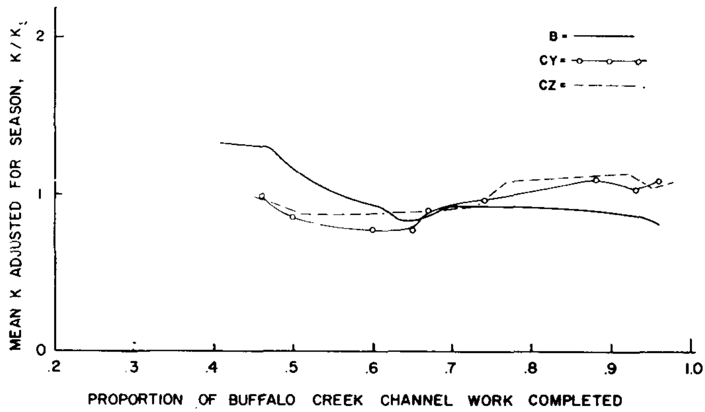

Fig. 8 — Changes in relative erodibilities during the nine-year period, 1953-1961, for Cayuga, Cazenovia, and Buffalo Creeks, New York.

8. Summary

Changes in sediment delivery rates as indicated by measured changes in flood water sediment concentrations indicated a reduction in sediment delivery of Buffalo Creek, New York, of about 40 percent. This was due to streambank stabilization works. Delivery of the other streams in the Buffalo River watershed increased by about 10 percent during the nine-year period, 1953-1961. The probable error in these estimates is about 8 percent.

A very large seasonal variation in watershed erodibility was found for all of the three streams. August values for sediment concentration or watershed erodibility were nearly three times larger than those for January.

Snowmelt runoff was equal in erosiveness to rainfall runoff for the relatively low rainfall intensities for which comparisons were made.

The measure of watershed erodibility generally increased with increasing time intervals between floods for those runoff events without snowmelt contributions. No trend of this kind was evident for floods with appreciable amounts of snowmelt.

Higher sediment concentrations at given stream flows at the Buffalo Creek Gardenville gage were found in flood water originating in the upper part of the watershed than for that from the lower areas.

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BEOBACHTUNGEN ÜBER BESONDERE EROSIONSERSCHEINUNGEN IM WINTER UND FRÜHJAHR 1962

H. KURON
Giessen

ABSTRACT

In the late winter and early spring 1962 there happened rather large soil losses by water erosion from loess loam slopes without vegetation cover. As there was only a very small and short lasting snow cover which could not provide large quantities of melting water, the effect must be explained by other peculiarities of weather. These were several frost periods alternating with warmer periods and rainfalls, which caused a complete water saturation of the soils and reduced infiltration to a miniumm.

RÉSUMÉ

L'hiver tardif et le printemps précoce de l'an 1962 ont provoqué des entraînements assez importants de sol sur les pentes de lehm, de loess sans couvert végétal par l'érosion hydrique. Comme le sol n'était recouvert que d'une mince couche de neige d'une courte durée, de grandes quantités d'eau de fonte de neige ne peuvent de ce fait être envisagées, ce phénomène doit être expliqué par d'autres particularités du temps. En effet, des périodes de gel dur ont alternè avec des périodes plus douces et des chutes de pluie et ont provoqué une saturation complète en eau des sols, réduisant la capacité d'infiltration au minimum.

ZUSAMMENFASSUNG

Im späten Winter und im zeitigen Frühjahr 1962 traten recht beträchtliche Bodenverluste durch Abschwemmung in Hanglagen mit Lösslehm ohne Pflanzendecke auf. Da nur eine sehr geringe Schneedecke von kurzer Dauer vorhanden war, die nur unbedeutende Mengen von Schmelzwasser lieferte, mußten die Erscheinungen durch andere Besonderheiten der Witterung erklärt werden. Sie beruhten in dem Auftreten mehrerer Frostperioden, die mit wärmeren Zeitabschnitten und Regenfällen wechselten. Dies bewirkte eine völlige Wassersättigung der Böden und verminderte die Einsickerung auf ein Minimum.

Im Spätwinter und Frühjahr 1962 traten auf unserem Ackerland allenthalben wieder einmal Abschwemmungen auf, wie sie in den entsprechenden Zeiten der vorangehenden Jahre nur vereinzelt zu vermerken waren. Wir nahmen die Gelegenheit wahr, diesen Erscheinungen auf den Lössböden im weiteren Umkreis von Giessen nachzugehen.

Für die weite Verbreitung des Abflusses großer Tagewassermengen und die damit verbundenen intensiven Bodenverschwemmungen war der Witterungsablauf und sein Einfluss auf den Bodenzustand verantwortlich. Unter Verwendung der Messwerte der Wetterstation Giessen sollen im folgenden die Voraussetzungen kurz gekennzeichnet werden.

Um die Jahreswende 1961/62 herrschte ein kräftiger Kahlfrost. Infolgedessen bildete sich auch ein tiefgreifender Bodenfrost aus. Mit Anstieg der Temperaturen löste sich dieser Bodenfrost ab 11.1. auf. Schon am 8.1. setzten leichte Regenfälle ein, die bis zum 13.1 insgesamt 14 mm Niederschlag lieferten. Durch entsprechende Regenfälle kamen in der Zeit vom 20. bis 27.1. weitere 19 mm auf den Boden. Dadurch erhielt der aufgetaute Boden bis gegen Ende Januar eine ständige zusätzliche Durchfeuchtung. Am 29.1. setzten erneut starke Fröste ein, die zumeist als Kahlfröste auf-traten. Anfang Februar war also der durchnäßte Boden wieder oberflächlich gefroren. Mit dem 2.2. setzten Niederschläge ein, die zunächst 5 mm als Schnee brachten. Mit erneutem Temperaturanstieg verwandelten sich die Niederschläge in Regenfälle, die in der Zeit vom 4. bis 12.2. je Tag 0 bis 5 mm, insgesamt 11 mm brachten. Die mittleren Tagestemperaturen lagen im wesentlichen zwischen 0° und 2°. Der Boden war offen. Bei dieser Situation fielen nun am 13.2. 29 mm Regen. Die durchnäßten Böden konnten diese Wassermengen nicht aufnehmen. So kam es in dieser Zeit zum ersten Mal zu starken Abflüssen in Hanglagen, und besonders auf den Lössböden traten schwere Abschwemmungsschäden in Erscheinung. Über die besondere Empfindlichkeit der schluffig-tonigen Lössböden gegen Abtrag wurde schon verschiedentlich berichtet. In diesem Falle kam ihre erhebliche Zerschlämmung als Folge der Durchnässung hinzu. Die eingeschalteten Fröste hatten zudem zu plattigen Abhebungen der Bodenoberfläche («Hochfrieren») geführt. Diese in sich verdichteten Platten verzögerten noch mehr die Einsickerung.

Es sei noch hervorgehoben, daß die hier betrachteten Lösslehme überwiegend zum Typus der Parabraunerden gehören. Es sind dies Böden, die in einer Tiefe von

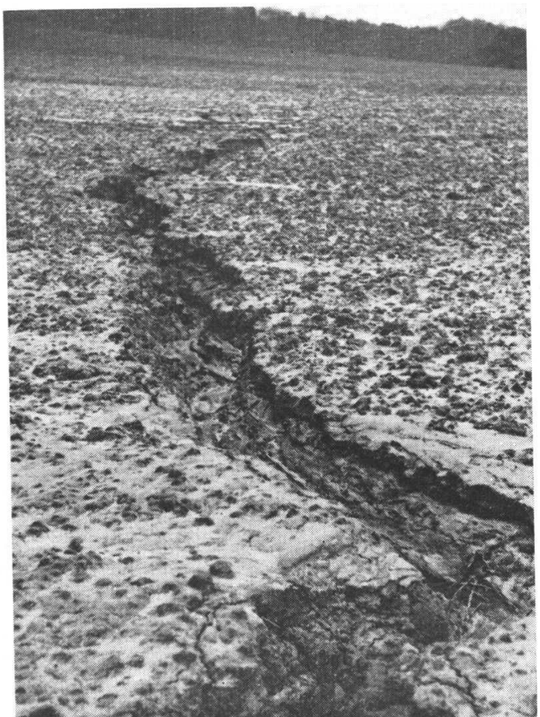

Fig. 1 — Erosionsanriß im oberen Teil des Hohlhanges

wenigen Dezimetern eine verdichtete Schicht, den B_t-Horizont, aufweisen, die ihre Entstehung der Einwaschung von Tonkolloiden aus dem Oberboden verdanken. Dieser Horizont fördert zusätzlich die Wasserstauung im Oberboden, zumal wenn er in erodierten Hanglagen nahe an die Oberfläche gerückt ist.

In den oberen Hanglagen und auf den Kuppen werden die Löss-Auflagen zum Teil sehr seicht, und unter ihnen stehen teils Basalt, teils Grauwackeschiefer an. Diese wenig durchlässigen Gesteine bewirken ebenfalls einen erheblichen Anstau von Sicker-