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ERODIBILITY OF SOME MICHIGAN SOILS

By

Somjate Jantawat

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ABSTRACT

ERODIBILITY OF SOME MICHIGAN SOILS

By

Somjate Jantawat

The soil erodibility of 142 soil samples from 28 sites covering seven soil series and four soil management groups located in different counties in the lower peninsula of Michigan were studied using Wischmeier's nomograph. Soil erodibility for three soil series was determined from actual soil loss under field conditions. It was found that the soil erodibility factor value determined from soil properties by using the erodibility nomograph had a specific range for each soil series. The soil series belonging to soil management group 1.5a have the highest values and soil series belonging to soil management group 4a have the lowest values. The erodibility factor value increases as the percentage of silt increases and decreases with the increase in percentage of sand. Mean and standard deviation of K-value for each soil series and soil management group were calculated.

Soil erodibility values obtained from Wischmeier's nomograph, U.S.D.A. Soil Conservation Service

and from measuring actual soil loss under field conditions were compared. It revealed that the K-values obtained from the nomograph and U.S.D.A. Soil Conservation Service were higher than the values obtained from measuring actual soil loss under field conditions for all soils. Therefore, the calculation of soil loss using K-values from the nomograph or U.S.D.A. Soil Conservation Service is an overestimation.

The effects of cropping systems and conservation practices on soil loss have been studied on three soil series and locations. It was found that the amounts of soil loss from plots with different management systems were significantly different for one location at Burton Street Farm and highly significantly different for the other two locations at Kalamazoo and Muskegon counties. Cropping systems which had high soil losses included several years of row crops. The amount of soil loss from plots decreased as the number of years of meadow in the cropping system increased. The amounts of soil loss from different conservation practices are significantly different. In plots with the same cropping system, contour tillage reduced soil erosion by half as compared with up and down slope cultivation. The influence of cropping system on soil erosion is greater than the influence of cultural practice especially on the plots with up and down slope tillage.

The effect of different management systems on soil organic matter was determined. The amount of organic matter under different cropping systems and cultural practices is highly significantly different. Cropping systems and conservation practices which reduced soil loss also increased the organic matter content of the soil.

Two kinds of pictorial graphs were prepared to present the soil loss data from erosion plots to young people. This will help these people to better understand the nature and control of soil erosion.

DEDICATION

To

My parents and my wife

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I. INTRODUCTION

Soil and water are two natural resources which are vital to the welfare of the nation. The loss of these resources has led to the destruction of many world civilizations. Soil erosion is considered the main cause for such losses. Man's struggle with soil erosion has continued since the day he started to farm. It has been recognized that man's failures in controlling erosion have been far more numerous than his successes.

In the United States, soil erosion by water is the dominant conservation problem on millions of acres of land in the humid portion of the country. Erosion from cropped lands results in drastic losses of soil and plant nutrients and, hence, causes reduction in soil productivity. It also results in poor efficiency of farm operation.

Sediment, a product of soil erosion, becomes a pollutant when it is deposited in reservoirs, settles on productive lands, destroys aquatic habitat, and creates turbidity that detracts from recreational use of water. Sediment carries with it significant quantities of plant

nutrients, pesticides, organic and inorganic matter, pathogens and other water pollutants. This aspect of soil erosion is possibly more important than the pollution consequences of the mineral sediments. Sediment when deposited in artificial reservoirs is reflected by the loss of storage capacity for water supply, flood control, power generation, navigation and regulation of streamflow for water quality control. Wearing or abrasion of power turbines, pumping equipment, irrigation distribution systems, and other structures is accelerated by sediment in the water.

In the United States, sediment damage has been estimated at more than 500 million dollars annually, and the storage capacity of manmade reservoirs is being reduced at the rate of about one million acre-foot each year (Freeman and Bennett, 1969). Some \$1.2 billion worth of nutrients are lost each year from croplands (Reinert and Oemichen, 1976). The total erosion rate per year for the contiguous United States is over 3.6 billion metric tons of which about 1.8 billion metric tons are washed into streams and 0.9 billion metric tons reach tide water (Aleti et al., 1974). At least half of the sediment comes from agricultural lands (U.S. Department of Agriculture, 1971). Soil loss from cultivated farm lands can exceed 200 tons per acre per year (Gottschalk and Jones, 1955), and rates as high as

127,000 tons per square mile per year have been reported (Gottschalk and Brune, 1950). The amount of soil erosion in the United States is likely to increase because lands which have been in set-aside programs and are vulnerable to erosion are being used for crop production. About nine million acres of noncultivated land was put into cultivation in 1974 and less than half of this land is being farmed with adequate erosion control (Rensberger, 1975). In 1974, about 60 million tons of top soil were lost from these areas. A recent report disclosed that nearly eight million acres of the Great Plains farmland were damaged by wind erosion during the winter and spring of 1977; this is the highest total in two decades (State Journal, 1977).

In the Great Lakes region, the gross erosion is more than 165 million tons annually, and only 3.3 percent of crop land (28.6 million acres) has adequate erosion control practices (Great Lakes Basin Commission, 1975).

For Michigan, the total soil loss was about 64,930,000 tons in 1974 (Hill, 1974). It has been reported that erosion rates in Michigan ranged from 7 to 48 tons per acre in 1975 (Quisenberry, 1975). Plant nutrients lost from different soils through erosion have been estimated as follows: 3 to 40 pounds per acre of nitrogen; 0.59 to 25 pounds per acre of phosphorus (P_2O_5) and 0.4 to 13.4 pounds per acre of potash (Lucas, 1975).

Soil erosion is increasing in Michigan because farms are becoming larger, fewer acres of pasture and

leguminous hay crops are grown, wooded property boundaries and woodlots have been cleared and weed populations have been reduced in both field and fence rows by increased application of herbicides (Robertson, 1975).

Little research has been done in Michigan on soil erosion to determine inherent erodibility. Recent studies of soil erosion in urbanizing areas were carried out by Ringler and Humphreys (1971) and Tilmann and Mokma (1976).

The present values (Michigan Department of Natural Resources, undated) of the soil erodibility factor for Michigan soils have been approximated by the U.S.D.A. Soil Conservation Service considering a soil's characteristics and tempering the estimated value of its erodibility against field observation. Recently, a soil erodibility monograph (Wischmeier et al., 1971) was used to determine the erodibility of groups of Michigan soils (Tilmann and Mokma, 1976). These values do not always agree with former erodibility values. In neither case were the erodibility values based on actual soil loss data. Conservationists and planners must know the erodibility of the soil if they are to design systems to prevent soil erosion and sediment pollution which are the goals of both state (Act 347) and federal (PL 92-500) legislation. Therefore, these values should be tested and reviewed to determine an accurate soil erodibility factor for Michigan soils.

The objectives of this study were to:

- (1) To determine soil erodibility of some Michigan soils by using the nomograph;
- (2) To determine soil erodibility of some soils by measuring actual soil loss from erosion research plots;
- (3) To compare the value of the soil erodibility factor which is derived from the nomograph, U.S.D.A. Soil Conservation Service, and measured soil loss under field conditions;
- (4) To determine soil loss from the plots with different cropping and cultural systems at three locations;
- (5) To prepare a simplified method of communication of soil loss data to young people.

II. REVIEW OF LITERATURE

Soil Erosion Research

Wollny has been named as a pioneer in doing rainfall erosion research in Germany in the latter half of the nineteenth century (Baver, 1938). His study involved the relation of soil erosion to steepness and orientation of slope, density of vegetative cover and soil type. Detailed discussions of Wollny's work were done by Baver (1938) and Stallings (1957). Wollny has been named as the father of soil conservation research (Nelson, 1958).

The first quantitative studies on soil erosion in America were carried out by the Forest Service in 1915 in Utah and by Miller in Missouri (Hudson, 1971). Other investigators soon followed using techniques by Miller and Duley (Smith and Wischmeier, 1962). Field plot data were first published in 1923 by Duley and Miller. Early research works in the United States were limited to measuring soil loss from different soil management systems. The mechanism of the soil erosion process was not studied during that period. Pioneer work in the soil erosion process was conducted in the 1930s by Musgrave (1934), Baver

(1937) and Borst and Woodburn (1938). The early history of soil erosion research in the United States has been well summarized by many authors (Nichols and Smith, 1957; Nelson, 1958; Harper, 1958; Smith and Wischmeier, 1962). The first detailed study of natural rain was carried out by Laws (1940) and the first analysis of the mechanical action of a raindrop on the soil was done by Ellison (1944a). Intensive studies of soil erosion by water were conducted by Ellison (1947a, 1947b, 1947c, 1947d, 1947e, 1947f, 1947g). Most of the early studies were discontinued by 1943, and additional basic investigations were started during and after World War II. The amount of soil movement on slopes increased with increasing gradient and length of slope, amount, depth and velocity of runoff (Lutz and Hargrave, 1944).

The development of a splash cup for soil erosion studies was accomplished by Bisal (1950). Force of raindrop impact on the sand surface was studied by Ekern (1950) and he found that the amount of fine sand transported by raindrops impact was directly proportional to the total mass of water supplied and to a factor representing the energy per unit area supplied by the individual drop. Fine sand gave the largest amount of transport by impact erosion. Physical aspects of the soil erosion process were described and defined. Soil erosion is the accomplishment of a certain amount of work in tearing and

transporting soil materials (Stallings, 1953). Detachability of soil varied with size and shape of particles and changing conditions within the same soil, including structure, organic matter content and influences of plant and animal life (Osborn, 1954). A method for measurement of permeability of surface crusts formed by splash erosion was developed (McIntyre, 1958). The relationship between splash erosion and the kinetic energy of natural or artificial rain was demonstrated (Rose, 1960). Studies of raindrop splash mechanics found that droplets less than 3 millimeters in diameter are nearly spherical (Mutchler, 1967). As diameter increases, drops become progressively more deformed. This results in a change in pressure distribution under the drop at impact due to this factor.

After field experiment data in the United States were published in 1923 (Duley and Miller, 1923), other parts of the world became interested in erosion study. For instance, in the Republic of South Africa, runoff plots were established at the University of Pretoria by Professor D. G. Haylett in 1929 and a second group was added in 1936 (Hudson, 1965). A similar installation was made in Napal in 1938.

Runoff experiments using large plots of several acres were started in Southern Rhodesia in 1934 and were neglected after a few years. However, experimentation

was resumed in 1955 at the Henderson Research Station and has been operated until today (Hudson, 1971). Erosion study plots were established by Staples in Tanganyika in 1938 (Van Rensberg, 1955). Laboratory study of the mechanics of soil erosion was conducted by Rose (1958) at Makerer College, Uganda, and van Heerden (1959) at the University of Pretoria. Both of them studied rain-drop splash by using a rainsimulator. In other countries outside Africa as described by Hudson (1965), field experiment studies on soil erosion were conducted in Sri Lanka, India, Puerto Rico, Australia and Japan during the last twenty years but only a few reports have been published (Ker, 1954; Mihara, 1959).

At the present time, soil erosion research is being done in many countries throughout the world because the loss of agricultural land due to erosion is a problem of worldwide concern. Numerous expenditures have been made to develop means of preventing or lessening the erosion that is associated with most agricultural activities.

Soil Erosion Process

The process of soil erosion by water has been discussed by a number of soil scientists including Bennett (1939), Ellison (1947a-g), Stallings (1953), Osborn (1955), Glymph (1957), Smith and Wischmeier (1962),

Robin and Neff (1963), Meyer (1964), Hudson (1965), Seginer (1966), Mutchler (1970), Foster and Meyer (1971), Young (1972) and Heede (1976). They defined the process of soil erosion by water as a complex process of detaching soil particles and transporting them down slope through the action of raindrop impact and runoff.

Baver (1933, 1937) and Smith and Wischmeier (1962) pointed out that the rate of soil erosion is determined by four factors which include: (1) climate, rainfall and temperature; (2) soil, its inherent resistance to dispersion and its water intake and transmission rates; (3) topography, particularly steepness and length of slope; and (4) plant cover, either living or the residues of dead vegetation. Ellison (1944b) reported that the four principal groups of factors affecting raindrop erosion are (1) characteristics of the cover, (2) characteristics of the soil, (3) characteristics of the slope, and (4) characteristics of the storm. Guinard (1968) also stated that the rate of soil erosion depends on various factors including climate, relief, soil type and vegetation.

Cook (1936) studied the process of soil erosion and concluded that the water erosion process is largely controlled by the following principal variables: (1) soil erodibility, (2) climatic erosivity, (3) infiltration capacity, (4) surface storage capacity, (5) degree of

slope, (6) length of slope, and (7) cover protectivity. Meyer (1964) studied the detailed mechanics of soil erosion by rainfall and runoff as influenced by slope length, slope steepness and particle size.

It has been recognized that man is a geologic agent, and Judson (1968) stated that man increases the rate of erosion by a factor of two or three as a result of poor management of the land. Brown (1970) reported that the rate of erosion in areas where humans are a significant factor varies between 15,000 and 85,000 $\text{m}^3/\text{km}^2/\text{yr}$ as compared with the rate of 12 to 1500 $\text{m}^3/\text{km}^2/\text{yr}$ from areas which are unaided by humans. A survey of man-induced soil erosion in the United Kingdom (Morgan, 1975) found that soil erosion increased after World War II because of increased cropland in this country and farming conditions changed as the economic and social environment altered and different crops were grown. The elimination of grass fallow and multi-cropping of the land where market-gardening is profitable exposes a large portion of the farm area to erosion. Douglas (1967) studied natural and man-accelerated erosion in the humid tropics of Australia, Malaysia and Singapore and found that the effects of agriculture on suspended sediment yield in stream increased from 900 $\text{m}^3/\text{km}^2/\text{yr}$ in 1911 to 1900 $\text{m}^3/\text{km}^2/\text{yr}$ in 1934 in Java due to gradually increasing deforestation, reckless cultivation and pasturing.

World erosion rate has been studied by a number of scientists. Judson (1968) reported the world erosion rate at the present time is higher than in the past due to intensive occupation by man. Holeman (1968) studied the sediment yield of major rivers of the world and found that rivers in Europe and Australia have very low sediment yield (less than 120 tons per square mile per year). South America's erosion rate is low, North America's is moderate, and Asia's is high to the degree of yielding up to 80% of sediment reaching the ocean annually. Another world erosion rate was studied by Stoddart (1969) and disclosed that the maximum rate of erosion in the seasonally humid tropics declined in the equatorial regions where the seasonal effect is lacking and in the arid regions where the total amount of runoff is low. In the desert, long-distance transport of sediment, except by wind, is nil. The rate of erosion is high in the seasonally wet Mediterranean lands, but in temperate and cold regions it is low except in mountainous areas. Young (1969) studied the present rate of land erosion and found that sediment yields from cultivated basins may overestimate geological rates of erosion by at least a factor of 2. Recent studies of world erosion disclosed that locally ion content varies with runoff depending upon climate but on the world scale, relief is the main factor controlling variations of dissolved solids (Meybeck, 1976).

Factors Affecting Soil Erosion

It has been considered for many years that severity of soil erosion at any place is governed by the interaction of four factors: climate, vegetation, topography, and soil. Although the occurrence of soil erosion depends primarily on the first three factors, even where these factors are alike the severity of soil erosion often varies, since soils differ in their ability to resist erosion. Bryan (1968a) described Bennett in 1926 as the first to recognize the variability of soil erosion resistant properties of soils. This variability has been described both as soil erosivity by Middleton (1930) and soil erodibility by Cook (1936). Soil erodibility was defined as the susceptibility of soil to erosion measured either by its resistance or its susceptibility to erosion (Cook, 1936). He also defined the erodibility index as the amount of erosion occurring under given controlled conditions. For practical and immediate use an index which may be determined by simple, rapid and fully controlled field tests is required.

Hudson (1971) defined soil erodibility as the vulnerability or susceptibility of the soil to erosion and it depends on both physical characteristics of the soil and the management of the soil. Wischmeier and Smith (1961) defined the erodibility of soil as soil loss in tons per acre per unit of erosivity index under

standard conditions of 9% slope, 72.6 ft. plot length, continuous fallow and plow up and down the slope. Erodibility was made a quantitative factor in the Universal Soil-Loss Equation.

Relation between Soil Erodibility and Soil Properties

Several soil scientists studying soil erosion have attempted to develop an index of the erodibility of soil by measuring physical properties of the soils and combining these in various ways. Bennett's (1926) initial work on soil erodibility was carried out on lateritic soils of Cuba. He determined the important soil properties influencing erodibility to be texture, structure, organic matter and chemical composition. A direct correlation between the silica-sesquioxide ratio and erodibility was found.

Middleton (1930) studied properties of soil which influence soil erosion and he was the first to attempt to devise an index of erodibility based on detailed laboratory analysis of samples from soils whose reactions to erosional processes were known from field observations. He found that the properties having the greatest influence on soil erosion are indicated by the dispersion ratio, the ratio of colloids to moisture equivalent, the erosion ratio, the dispersion ratio divided by the ratio of colloid content to moisture equivalent and the silica-sesquioxide ratio.

Lutz (1934) studied the physio-chemical properties of soils affecting soil erosion and found that physical properties of soils affecting permeability and the ease of dispersion are the paramount factors influencing the erodibility of the various soils.

Baver (1933) observed that absorptive capacity of water, permeability of soil profile, ease of dispersion, size of particle and degree of aggregation affect erosion. Cook (1936) reported that soil erosion is affected by (1) distribution of particle sizes, (2) the state of aggregate or structure of the soil, (3) the moisture content, (4) the density or compactness of the soil in place, (5) certain chemical constituents, and (6) the biological condition of the soil.

Bouyoucos (1935) expressed the erodibility of soil as the ratio of the percentage of silt and clay to the percentage of clay with a useful range limited to above 10%. This was named the clay ratio. Peele (1937) concluded that percolation rate, suspension percent and dispersion ratio appear to be good indices of relative erodibility of soils. Anderson (1954) developed the surface-aggregation ratio as the index of soil erodibility and defined it as the ratio between the total surface area of particles larger than 0.05 mm diameter and the quantity of aggregated silt and clay. Adams et al. (1958) found a negative correlation between

splash or wash erosion and percentage of water-stable aggregate greater than 2.0 mm and a positive correlation between wash erosion and rainfall intensity.

Barnett et al. (1965) reported total erosion was directly related to soil texture, initial soil moisture, and storm size. The soil erodibility factor increased as the texture changed from sand to loamy sand to sandy loam to sandy clay loam to silt loam. Barnett and Rogers (1966) studied soil physical properties related to runoff and erosion under artificial rainfall and used multiple regression analysis and found that multiple factor regressions were fitted to those soil-site physical parameters found to be most useful in predicting soil erodibility and runoff potential from cultivated fallow soil under artificial rainfall.

Dyrness (1965) found that factors strongly influencing these erodibility indices include soil parent material, organic matter content, climatic conditions and chemical properties. Yamamoto and Anderson (1967) reported parent rock material was the most important factor in explaining variation of water stable aggregate of soil in Hawaii; nevertheless, differences in water stable aggregates were also associated with differences in vegetation types and other soil forming factors. Epstein and Grant (1971) indicated that the erodibility of different soils may be related to the rate and extent

to which surface crust forms. Bryan (1967) studied relative erodibility of some soils in the United Kingdom and found that the most efficient indices for general use are the erosion ratio, the surface-aggregate ratio. However, erosion ratio and dispersion ratio were found to be relatively inefficient for soil of low silt plus clay content, confirming the findings of Adams et al. (1958) and Olson and Wischmeier (1963).

Wischmeier and Mannering (1969) expressed the erodibility as an empirical function of 15 soil properties and their interactions. This equation is valid for a wide range of American soils but is complex. Barnett et al. (1971) tested Hemates clay, Juncos clay and Pandura loam soils by field plot studies under simulated rainfall. The soils were found to be in order of their increasing erodibility and decreasing infiltration. Ekasingh (1971) studied the relationship between soil erodibility and infiltration rate in Great Britain and found that infiltration rate was not a good index of soil erodibility.

Epstein and Grant (1971) investigated soil surface properties as affected by soil erodibility under simulated rainfall and found that soil erodibility is a function of two components--detachment and transportation. The detachment of soil particles is affected by soil surface conditions as well as rainfall characteristics.

Wischmeier et al. (1971) simplified the erodibility equation (Wischmeier and Mannering, 1969) to the most important five soil parameters which are percent silt, percent sand, percent organic matter, structure and permeability. He translated it into a nomograph which can give a quick solution to erodibility value of soils to use in the Universal Soil-Loss Equation (Wischmeier and Smith, 1965).

Choudry (1973) studied the erodibility of some tropical soils by using Wischmeier's (1971) nomograph and determined soil loss under rainfall simulation in the laboratory. He found that with respect to particle size distribution of soils, the erodibility did tend to decrease with greater sand and increase with greater silt contents.

Determination of Soil Erodibility

Assessment of soil erodibility may be made on the basis of soil-loss measurement under controlled conditions or on the basis of certain indices of erodibility. Measurements of soil-loss under controlled conditions are expensive and require elaborate installations and observations for lengthy periods. Indices of erodibility can usually be derived from normal analytical data, therefore requiring little special equipment. They can be measured rapidly for a large

number of soils and are, therefore, very suitable for mapping of soil erodibility as a stage in land use planning.

Evaluation of the relative efficiency of erodibility indices requires direct measurement of the erosional behavior of soils under specified conditions of slope, vegetation and rainfall which can be used as a reference standard. Such measurements may be obtained either from field runoff plots under natural rainfall or small samples subjected to artificial rainfall in a laboratory.

Bryan (1968b) reported that field runoff plots have the advantage of using undisturbed soil and natural rainfall but suffer from a number of disadvantages. They are expensive to construct; and if agricultural land is involved, permission may be difficult to obtain. Although the use of natural rainfall is an advantage, it is necessary to continue observation for a very long time to duplicate certain conditions of soil moisture and juxtaposition of rainstorms. Because they cannot be used at a large number of sites, they allow examinations only of the surface horizons. While some of the disadvantages may be avoided by using artificially simulated rainfall on field runoff plots, the need for a large water supply renders the arrangement inflexible. The great advantages of the use of simulated rainfall

are the replicability of rain conditions, the elimination of all variables except soil type, and the possibility of testing samples from any depth in the profile. The chief disadvantage is that any form of simulated rainfall can only partially reproduce the characteristics of natural rainfall. The method of simulation used determines the degree of realism of the reproduction.

The pioneer work using field runoff plots was done by Duley and Miller (1923), the techniques being subsequently employed widely by the U.S.D.A. Soil Conservation Service. Detailed discussion of the simulation of rainfall for soil erosion research was done by Meyer (1965) and the limitation of simulated rainfall as a research tool was described by Mech (1965). The reviews of artificial rainfall simulators were made by Hudson (1964) and Mutchler and Hermsmeier (1965). The discussion of construction of a rainfall simulator for runoff plots was carried out by Ellison and Pomerence (1944), Meyer and McCune (1958) and Hermsmeier et al. (1963). The design of plot experiments for measurement of runoff and erosion was described by many investigators including Brandt (1941), Hudson (1957), Mutchler (1963) and Hayward (1969).

The determination of soil erodibility by using a rainfall simulator under field conditions and in the laboratory has been performed by many soil scientists

(Adams et al., 1958; Ballal and Deshpande, 1960; Olson and Wischmeier, 1963; Barnett et al., 1965; Barnett and Rogers, 1966; Bryan, 1967; Epstein and Grant, 1971).

Recently, development of the method of determining soil erodibility by using a rainfall simulator was described by Bruce-Okine and Lal (1975), and they found that erodibility varies directly with sand and inversely with clay content. They proposed this method for routine laboratory evaluation of erodibility of soil.

Another method, different from previous methods, was developed by Chandra and De (1973). They found that the IR-absorption spectra of uneroded and eroded soils of semi-desert, arid, semi-arid, and subhumid types in India are different and the technique can be used to characterize more erodible soils from erosion resistant soils. This is because fertile soils have comparatively greater number of peaks than the infertile soils. Eroded soils are generally known to be less fertile due to physical removal of fine soil particles, nutrients and organic matter and thus result in lower number of IR-peaks.

Simonyan and Galstyan (1974) proposed another technique to determine soil erodibility. They studied the relationship between the activity of enzymes including invertase, phosphatase, urease, catalase, and dehydrogenase and the degree of erosion of Chernozems, mountain

meadow, Brown Forest Steppe, Chesnut and Brown Semidesert soils of the Arminian USSR, and they reported that the method of enzymic reactions made it possible to characterize the biological activities of the eroded soils and to reveal features of the soil erosion process and found that eroded soils had lower biological activities than uneroded soils and the most suitable enzyme for diagnosis of eroded soils was invertase.

The soil erodibility factor is another factor which is being studied and revised in some areas. Tilmann and Mokma (1976) estimated soil erodibility for soil management groups in Michigan by using Wischmeier's nomograph method and their values are different from the values established by the U.S.D.A. Soil Conservation Service.

Estimation of Soil Loss

Soil erosion is a complicated process involving many factors and the amount of soil loss depends upon such variables as soil type, degree and length of slope, the crop grown and the manner of their cultivation, the rainfall, and so on almost indefinitely. Furthermore, there are interaction effects between many of the separate factors, so that it is almost impossible to arrive at a precise mathematical solution to the problem (Hudson, 1965).

A number of formulas have been used to introduce a mathematical basis into either prediction of soil loss or recommendation for land use which will limit erosion to permissible value. Baver (1933) was one of the first to attempt a mathematical descriptive expression for the erosion process. His expression can be written as follows:

$$E = f(R,G,V,S)$$

where:

E = erosion

R = a factor for the amount and intensity of
rainfall

G = a factor for the slope and area of land

V = a factor for the amount and nature of vege-
tation

S = a factor for soil characteristics

Development of an equation for calculating field soil loss began about 36 years ago in the corn belt states (Wischmeier and Smith, 1965). Two systems were involved, one in the corn belt states and another in the northeast states. This latter equation is frequently referred to as the Musgrave Equation for computation of gross erosion from watersheds. Zingg (1940) was the first investigator introducing the equation for calculating field soil loss by using data from earlier research in the United States

up to 1939. He analyzed these data and concluded that soil loss is proportional to the 1.40 power of the land slope in percent and soil loss in tons per acre is proportional to 1.6 power of the horizontal length of the slope. The equation for calculating soil loss may be written as follows:

$$X = CS^{1.4}L^{1.6}$$

where:

X = the total soil loss in tons per acre per year

C = a constant of variation

S = the land slope in percent

L = a horizontal length of slope in feet

Smith (1941) modified Zingg's equation by adding crop and conservation practice factors and the limiting annual soil loss concept in development of a method for applying conservation practices to the Shelby and associated soil of the Midwest. Browning et al. (1947) developed a new equation which is derived from Smith's equation by adding soil erodibility and management factors to the equation. They prepared a set of tables to facilitate field use of the equation, and this system was used throughout the state of Iowa. The equation is expressed as follows:

$$A = P.T.R.E.F.L.^{0.6}S^{1.4}$$

where:

- A = soil loss in tons per acre per year
- P = a factor depending on the conservation practices (e.g., 1 for corn in rows straight up and down hill, 0.5 for strip cropping)
- T = a factor reflecting relative erodibility of the soil type
- R = a factor for various standard rotations
- E = the degree of past erosion
- F = a fertility factor representing the amount of fertilizer or manure applied
- L = the length of slope in feet
- S = the slope of the ground in percent.

Smith and Whitt (1948) developed a method of calculating soil loss for the Midwest claypan soils and an adaptation of the method for the principal soils of Missouri. A national committee on soil-loss prediction met in Ohio in 1946 to adapt the Corn Belt Equation to other cropland areas with erosion problems (Musgrave, 1947). This committee reappraised the corn belt factor values and added a rainfall factor. The resulting formula is generally known as the Musgrave Equation as mentioned earlier. Lloyd and Eley (1952) developed a graphical solution of the equation

in 1952 which is used by the U.S.D.A. Soil Conservation Service in the northeastern states.

An improved soil-loss equation developed in the latter part of the 1950s (U.S.D.A. Agricultural Research Service, 1961; Wischmeier and Smith, 1961) overcame many of the limitations of the earlier equations. The improved equation was developed at the Runoff and Soil-Loss Data Center of the Agricultural Research Service, established at Purdue University in 1954. Most of the basic soil erosion data obtained in studies in the United States since 1930 were assembled at this center for summarization and further analyses. By using advanced techniques of analyzing, these analyses resulted in several major improvements that were incorporated in the new soil-loss equation: (1) an improved rainfall-erosion index (Wischmeier, 1959); (2) a method of evaluating cropping management effects on the basis of local climatic conditions (Wischmeier, 1960); (3) a quantitative soil-erodibility factor; and (4) a method of accounting for effects of interrelations of such variables as productivity level, crop sequence, and residue management. These improvements freed the equation from some of the generalizations of the geographic and climatic restrictions inherent in earlier models.

Wischmeier and Smith (1965) described the use of the present soil-loss equation which can be expressed as follows:

$$A = RKLSCP$$

where:

- A = the computed soil loss per unit area in tons per acre per year
- R = the rainfall factor which is the number of the erosion-index units in a normal year rain. The erosion index is a measure of the erosive force of specific rainfall.
- K = the erodibility factor and is the erosion rate per unit of erosion index for a specific soil in cultivated continuous fallow on a 9% slope, 72.6 feet long
- L = the slope length factor and is the ratio of soil loss from the field slope length to that from a 72.6 feet length on the same soil type and gradient
- S = the slope gradient factor and is a ratio of soil loss from the field gradient to that from a 9% slope
- C = the cropping management factor and is the ratio of soil loss from the field with

specific cropping and management to that from the fallow condition on which the K factor is evaluated

P = the erosion control practices factor and is the ratio of soil loss with contouring, strip cropping or terracing to that with straight row farming up and down slope.

Factors Involved in Soil-Loss Equation

The Rainfall Factor (R)

A number of scientists studied the relationship between rainfall and soil erosion. Law (1940) was the first investigator who made a detailed study of natural rain and soil erosion. A few years later, Ellison (1944a) studied a laboratory experiment measuring splash erosion for various combinations of drop size, velocity, and intensity. He proposed the relationship between rainfall characteristics and splash erosion as follows:

$$S \propto V^{4.33} \times D^{1.07} \times I^{0.65}$$

where:

S = the grams of soil splash in 30 minutes

V = the drop velocity in feet per second

D = the drop diameter in mm

I = the rainfall intensity in inches per hour

A similar experiment was conducted by Bisal (1960) and he expresses these relationships as follows:

$$G = KDV^{1.4}$$

where:

G = the weight of soil splash in grams

K = a constant for the soil type

D = a drop diameter in mm

V = the impact velocity in meters per second

In Japan, Mihara (1959) studied the effect of kinetic energy on splash erosion and concluded that splash erosion is directly correlated with kinetic energy. This result was in accordance with that of Free (1960). Rose (1960) also found that the rate of detachment depends more closely on momentum than energy. However, it has been shown by Hudson (1971) that for natural rain, the relationships between intensity and either momentum or kinetic energy are equally close and are of the same pattern. Hay, as described by Musgrave (1947), was the first worker to show that erosion at La Crosse, Wisconsin Station was correlated with the maximum amount of rainfall occurring within any 30-minute period. He further reported that with other things being equal, erosion was found to be approximately

proportional to $P_{30}^{1.75}$, where P_{30} represents the maximum amount of rainfall occurring in any 30-minute period.

Musgrave (1947) included a rainfall factor for estimation of soil loss from the field. Wischmeier et al. (1958) introduced a new parameter for rainfall. This variable is the product of the rainfall energy and 30-minute intensity of the rainstorm. This term measures the interaction effect of these two storm characteristics and is referred to as erosion index or EI value. Wischmeier (1959) described the development of a rainfall erosion index for a Universal Soil-Loss equation and concluded that the rainstorm characteristic which best estimates soil loss is the variable whose value is the product of the rainfall energy and maximum 30-minute intensity of the storm (designated as EI_{30}).

Hudson (1971) reported in Africa that the EI_{30} index was not as efficient as that claimed by Weischmeier's studies in the U.S.A. He proposed a KE 1 index which means the total kinetic energy of the rain falling at an intensity of more than one inch per hour. It can be used exactly in the same way as EI_{30} but, according to Hudson, appeared to be more appropriate than EI_{30} for the tropical and subtropical rainfall. However, Kinnell (1973) reported that the kinetic energy of rainstorm, as used in the index, was computed from empirical intensity and drop size distribution relations and

might be subjected to errors since the relationships were apparently influenced by rain types and geographical locations. Stocking and Elwell (1973) suggested that EI_{30} index worked best for bare soil in Rhodesia but indices with shorter intensity periods (e.g., EI_{15} or EI_5) may be better predictors of soil loss in soils with high infiltration rates and/or good vegetative cover. Recent research done by Wilkinson (1975a) in Western Nigeria revealed that runoff and soil loss on bare soil are closely related to an EI_{30} -erosivity index, modified by time position of the peak intensity.

Kowal and Kassam (1976) used a specially designed instrument to give a continuous record of the number and size of raindrops with time. This instrument can be used to measure the instantaneous intensity and energy load of a rainstorm. They concluded that both the intensity and drop size of rain in tropical West Africa are much greater than in a temperate climate and the higher intensity of tropical storms is due to the larger size and greater number of raindrops falling per unit time. A high correlation between the average drop volume of rainfall and the amount of rainfall allows for a reliable and convenient estimate of the energy load of storms from the amount of rainfall.

The R factor in the soil loss equation is the erosion potential of rainfall in a particular locality,

that is, the ability of rain to erode soil from fields. Wischmeier and Smith (1958) and Wischmeier (1962a) stated that soil loss measurements show that the erosion potential is not necessarily determined by the total amount of rainfall or any specific intensity frequency. However, Wischmeier (1959, 1962b) reported that the best indicator of rainfall erosion potential now known is the rainfall-erosion index.

The rainfall-erosion index is a function of the characteristics of each individual rainstorm. Analysis of extensive soil-loss data and associated rainfall records revealed that when factors other than rainfall are held constant, soil losses from cultivated fallow fields are directly proportionate to the product of two rainstorm characteristics--total kinetic energy of the storm times its maximum 30-minute intensity. The rainfall-erosion index for a given time period is the sum of the EI values computed for individual storms occurring during the period. The average annual value of the erosion index in any specific locality is the rainfall factor (R) for the soil-loss predicting in that locality (Wischmeier, 1959, 1962b). In Michigan, rainfall factors for different counties were calculated from an iso-erodent map (Wischmeier and Smith, 1965) by Tilmann et al. (1975) and are shown in Appendix A.

Soil-Erodibility Factor (K)

Different types of soil erode at different rates even when other factors affecting erosion are constant. Many investigators reported that some of the important soil physical properties that influence erodibility are size and stability of structure; texture; percentage of coarse fragments, especially on the soil surface; organic matter; infiltration; permeability; type of clay mineral; and depth of soil material (Smith and Wischmeier, 1957; U.S.D.A., ARS, 1961; Wischmeier and Smith, 1965; Wischmeier et al., 1958; Wischmeier et al., 1971).

The soil erodibility factor (K) in the erosion equation reflects the rates at which different kinds of soils erode. "K" values are expressed as soil loss in tons per acre per unit of rainfall-erosion index (R) from clean-tilled continuous fallow on a 9% slope, 72.6 feet long (Wischmeier et al., 1958; Wischmeier and Smith, 1961; Wischmeier and Smith, 1965). The basic slope of 9% and 72.6 feet long was selected since these were the specifications of many plots used in early runoff and erosion experiments. Continuous fallow is defined as any land that has been tilled and kept clear of vegetation for a period of at least two years or until prior crop residues have decomposed (Jent et al., 1967).

Browning et al. (1947) introduced soil erodibility as a factor of soil-loss equation and subsequently other

scientists tried to develop erodibility indices of soil (Middleton, 1930; Bouyoucos, 1935; Peele, 1937; Anderson, 1951, 1954; Woodburn and Kozachyn, 1956; Wallis and Steven, 1961; Wooldridge, 1964; Willen, 1965; Wischmeier and Mannering, 1969).

Recently, Wischmeier et al. (1971) developed a method to determine soil erodibility by using the five most important soil parameters which are percentage of sand, silt, organic matter, structure and permeability. These properties were related in a nomograph which can give quick solution to the erodibility value of soils, to use in the Universal Soil-Loss Equation. Values of K were determined for 23 major soils on which erosion plot study was conducted since 1930 (Wischmeier and Smith, 1965). Erodibility values for numerous other soils have been approximated by considering a soil's characteristics and tempering the estimate of its erodibility against the established values for the 23 soils. The K values of Michigan soils have been developed by the U.S.D.A. Soil Conservation Service using this method and are shown in Appendix B.

Length and Steepness of Slope Factors (LS)

Soil losses are greater on longer and steeper slopes, but the rate of erosion does not increase uniformly with increasing slope length or gradient. Soil

losses per unit area have been found to increase exponentially with increase in slope length and steepness. The exponent in common used for increasing length is 0.50 and the exponent presently used for increasing steepness is 1.40 (Wischmeier et al., 1958; Zingg, 1940).

Solution of the soil-loss equation is made easier by combining the equations of the factors for length and steepness of slope and expressing them as a ratio of soil loss for any slope length and steepness to the "standard" 9%, 72.6 foot long slope. With the value for the "standard" set at 1 or any other value, charts or tables may be prepared for easy selection of LS ratios (Wischmeier and Smith, 1965; Wischmeier et al., 1958). When using the soil-loss equation to estimate soil loss, the length of slope is the distance from the point where overland flow begins to do either of the following, whichever is limiting for the major part of the area under consideration: (1) the point where runoff water becomes concentrated in a watercourse that may be part of a drainage network or a constructed channel such as a terrace or diversion, or (2) the point where the slope decreases to the extent that deposition begins (Wischmeier and Smith, 1965).

The slope-effect chart assumes essentially uniform slopes. Field slopes are often either concave or convex. The effects of concavity or convexity of slopes

on erosion rate has been recently determined by Wischmeier (1974). The slope-effect chart is shown in Appendix C.

Values of LS for slope percentage not shown on the chart may be computed by solving the following equation:

$$LS = \sqrt{\lambda(0.0076 + 0.0053s + 0.00076s^2)}$$

where:

λ = the field slope length in feet

s = the gradient expressed as slope percent

These factors can be estimated separately as follows:

$$L = \left(\frac{\lambda}{72.6} \right)^{0.5}$$

$$s = \frac{0.43 + 0.30s + 0.043s^2}{6.613}$$

where:

λ = the field slope length in feet

s = the gradient expressed as slope percent

The Cropping-Management Factor (C)

Wischmeier and Smith (1965) stated that the effects of cropping and management variables cannot be evaluated independently because of the many interactions

involved. Almost any crop can be grown continuously, or it can be grown in any one of numerous rotations. The sequences of crops within a system can vary. Crop residues can be removed, left on the surface, incorporated near the surface, or plowed under. When left on the surface, they can be chopped or allowed to remain as left by the harvesting operation. Seedbeds can be left rough with much available capacity for surface storage of rainfall, or they can be left smooth. Different combinations of these variables are likely to have different effects on soil loss. In addition, the effectiveness of crop-residue management will depend on how much residue there is. This, in turn, depends on rainfall distribution, on the fertility level, and on various management decisions made by the farmer.

The canopy protection of crops not only depends on the type of vegetation, the stand, and the quality of growth, but it also varies greatly in different months or seasons. Therefore, the overall erosion-reducing effectiveness of a crop depends largely on how much of the erosive rain occurs during those periods when the crops or management practices provide the least protection.

Wischmeier and Smith (1965) defined the factor C in the soil-loss equation as the ratio of soil loss from land cropped under specified conditions to the corresponding loss from tilled, continuous fallow. Jent et al.

(1967) stated that the cropping management factor is the most complex of all the factors in the equation. When a field is cropped or certain management practices are used, the amount of erosion may be greatly reduced. How much depends on many factors and their interaction effect on each other. Further detailed discussion on the C factor has been done by Wischmeier (1960), Wischmeier and Smith (1965), and Wischmeier et al. (1958), Jent et al. (1967) and Bone et al. (1975). This factor is introduced to estimate soil-loss from field area by Browning et al. (1947). It has been revised and improved by Wischmeier (1971, 1973, 1974). The C factor for Michigan is shown in Appendix D.

Crop Rotation and Soil Erosion

Smith (1946) reported that crop rotation provides two effects viz. soil conditioning and crop cover protection for the soil. He further mentioned that crop cover dissipates the energy of falling rain and develops a soil condition that will resist erosion. Page and Willard (1946) studied the effect of cropping systems on soil properties and found that continuous cropping to grain crops leads to a decline in the productivity level and in favorable soil structure. Conversely, where liberal amounts of organic matter have been returned to the soil, soil structure and productivity have not been affected as adversely. Where sod crops were included in

the rotation, marked improvement has resulted and the greatest improvement has resulted from a combination legume-grass mixture.

It has been recently reported by Bolton and Aylesworth (1972) that crop rotation increases soil total pore space. Browning (1946) studied seasonal distribution of soil moisture under different crops and found that the moisture content varies with depth in the soil and is influenced by the water requirement of the plant and type and distribution of the roots of the crop being grown. He further mentioned that alfalfa reduced the soil moisture content considerably more than corn-oats-meadow rotation and continuous bluegrass.

Duley and Miller (1923) reported that when the soil is dried by a close growing crop, the total absorption is greater than that of uncropped or row cropped soils which contain more total moisture. This effect of the close-growing crop is also shown in the result from the rotation system which absorbed much more water than the cultivated land. He also mentioned that crop rotation reduces erosion because the land will be covered with a growing crop a very large portion of the time.

Hudson (1971) suggested that soil loss from erosion is nearly proportional to the exposed ground surface. Wilkinson (1975b) described the canopy in

annual crops as a function of time of planting, plant spacing, growing habitat (varietal differences), soil fertility, moisture stress, disease and insect incidences. The interaction of crop season and cultural practices more or less dictates canopy characteristics and soil exposure.

Uhland (1949) suggested that crop rotation for most effective soil and water conservation must possess the following characteristics: (1) supply cover or protection of the proper kind and amount at the time when it is needed; (2) condition the soil with vigorous growing grasses and legumes to resist erosion when clean-tilled crops are grown; (3) include cover crops to supply organic matter and as near year-round protection as possible; (4) include use of soil amendments and fertilizers for effective erosion control, maintenance of organic matter and economic production; (5) provide for the best use of crop residues, manure, and cover crops, especially while land is in row crops; (6) include other needed supporting soil and water conservation practices, such as contouring, strip cropping and terracing.

The Erosion Control Practice Factor (P)

The factor P in the erosion equation is defined as the ratio of soil loss with the supporting practice to the soil loss with up and down hill culture. The

experimental plots from which the erodibility values were determined were fallow and cultivated up and down hill. The P factor values to measure the effects of contour farming, contour strip cropping and terracing or certain combinations of these were established in 1956 and data used came from research results from using these practices at three different locations--La Crosse, Wis., Bethany, Mo., and Urbana, Ill. (Jent et al., 1967).

Contour farming is an effective conservation practice when properly used. Its effectiveness depends on row ridges made with tillage implements which retard water running down hill. Soil loss from contoured fields may range from 100% to 50% of that expected from up and down tillage, depending on the steepness of slope (Jent et al., 1967). Contouring appears to produce its maximum average effects on medium slopes. As the slope decreases, the erosion control effectiveness becomes less. As the slope increases, the amount of water retained by contour rows decreases and the rate of soil loss increases. Contouring provides almost complete protection for individual storms of low intensity, but for severe storms that cause excessive row breakage, it provides little or no protection.

Soil loss under contour strip cropping averages about 50% of that from contouring alone. However, this reduction only considers the off-field movement of soil.

Much of the soil washed from cultivated strips in a contour strip-cropped field is filtered out in the first few feet of the meadow strips. Soil movement and sedimentation within the field are not accounted for by the contour stripcropping factor.

Field stripcropping is growing crops in strips or bands across the general slope following the land contour where possible. Crops which are arranged so that a strip of grass or close-growing crop alternates with a clean-tilled crop are more effective in reducing soil loss than contouring alone, but less effective than contour stripcropping.

The contour stripcropping factor value is based on the cropping systems used in the research work. This was a corn-small grain-2 years meadow rotation with meadow strips alternating with grain. When the cropping system used in stripcropping is less effective, a larger factor value should be used which will reflect the reduced effectiveness of the rotation in reducing soil loss.

Terraces intercept and divert water running down the slope before it reaches velocities that cause damaging erosion. Soil saved is due to the shortened slope length and deposition in the terrace channel along with the effectiveness of contour farming. Wischmeier and Smith (1965) reported that if all furrow slices between

terraces were turned up slope periodically with a two-way plow, most or all of the soil washed into the terrace channel would be effectively moved back up the slope and a factor value based on the off-the-field rate of loss could be safely applied. Limited data indicates that the terrace factor in this case should be about 20% of that for contouring. But in most farming practices, conventional plows are used and the soil deposited in the terrace channel is not returned to the interterrace interval to help maintain soil productivity.

Jent et al. (1967) stated that it is logical to assume that the total movement of soil within a terrace interval is equal to that with contouring alone on the same length and percentage of slope. Erosion control between terraces depends upon the crop rotation and other management practices. Therefore, if a control level is desired that will maintain soil-loss tolerance limit, the practice factor for terracing should equal the contour practice factor.

Erosion control practice factor was introduced to use as a factor for calculation of soil loss equation by Smith (1941). This factor (P) has been revised recently by Wischmeier (1973), in which various types of tillage operation providing different P values for the Universal Soil-Loss Equation have been considered. The values for the P factor for Michigan are shown in Appendix E.

Soil Loss Tolerance Value (T)

Jent et al. (1967) defined soil loss tolerance (T) value as the estimated average annual soil loss that can be tolerated and yet achieve the degree of conservation needed for sustained, economical production in the foreseeable future. It is expressed as average annual soil loss in tons per acre per year. Tolerance value gives meaning to the soil loss predicting equation. A comparison of the calculated predicted soil loss (A) arrived at through use of the equation with the tolerance value (T) for a soil indicates the degree to which the present cropping management and conservation practices are adequate. Furthermore, such comparison suggests the kind of cropping management and conservation practices needed to keep predicted soil losses equal to or less than the tolerance rate for the field under study (U.S.D.A., ARS 1961; Wischmeier and Smith, 1965).

Establishment of the T values was based on research data, experience and knowledge of the characteristics of each soil series. This includes such criteria as soil properties, soil depth, rooting depth, permeability and prior erosion (Bone et al., 1975). It is generally agreed that maximum soil loss tolerance for even the most favorable situation should not be greater than 5 tons per acre per year (Jent et al., 1967). In Michigan, maximum soil loss tolerance value is 5 tons per

acre per year (U.S.D.A. Soil Conservation Service, 1973). Smith (1941) introduced the concept of soil loss tolerance values in development of a method for applying conservation practices to some soils of the Midwest.

Reliability of Soil-Loss Equation

The soil-loss equation was designed to predict long-time average soil losses for a specific combination of rainfall pattern, topography, soil, cropping, management, and productivity level (Wischmeier and Smith, 1961). The major limitation of the universal soil-loss equation is the lack of sufficient research data for evaluation of some of the factors in specific areas.

It has been reported by CAST (1975) that the universal soil-loss equation cannot be used in the loessial regions of Washington, Idaho and Oregon. Wischmeier (1976) stated that the universal soil-loss equation was designed to predict soil loss from the field area by sheet and rill erosion only. Soil loss from gully and streambank erosion cannot be estimated by this equation. He identified potential sources of error in factor values for the universal soil loss equation.

The universal soil loss equation has been adapted for use in Hawaii (Brooks, 1977). In the adaptation and application of the universal soil loss equation in West Africa, the R factor had to be modified (Roose, 1977).

Wischmeier (1974) stated that the R factor which has been established and used only within the 37 states east of the Rocky Mountains is presented in terms of an iso-erodent map (Wischmeier, 1959, 1962b; Wischmeier and Smith, 1965). The map was not extended to the Pacific Coast because the precipitation patterns in the mountainous states are highly localized and the available long duration recordings (rainfall records) did not provide sufficient coverage to characterize the geographic distribution of EI values in those states. However, the development of EI values for this region was carried out by the Agricultural Research Service, and they proposed $EI = 27.38P^{2.17}$, where P is the 2-year, 6-hour rainfall in inches in 1969 (Wischmeier, 1974). The U.S. Environmental Protection Agency (1973) modified the previous equation after making intensive study on the R factor for these states. The new equation can be expressed as $EI = 16.55P^{2.2}$.

Ateshian (1974) made recent studies of the rainfall erosion index of the United States and proposed two types of equations to estimate EI. They can be written as follows:

$$\text{Type I: } \frac{EI}{100} = 2.176(P_{24 \text{ hr}})^{2.2}$$

$$\text{Type II: } \frac{EI}{100} = 4.365(P_{24 \text{ hr}})^{2.2}$$

in which P_{24} is rainfall amount in inches for a 24-hr duration storm. Type I is representative of Hawaii, Alaska, and the coastal side of the Sierra Nevada and Cascade Mountains in California, Oregon, and Washington. Type II is representative of the rest of the United States, Puerto Rico, and the Virgin Islands.

In Rhodesia, Stocking and Elwell (1974) found that EI_{30} is the most generally applicable erosivity parameter over large areas of bare soil. Wilkinson (1975a) also found that runoff and soil loss on bare soil in Nigeria are closely related to an EI_{30} erosivity index, modified by the time position of the peak intensity.

Dangler and El-Swaify (1976) determined soil erodibility for tropical soil in Hawaii by using rainfall simulator and found that these erodibilities are strongly related to such properties as aggregate stability, clay and sesquioxide contents and soil acidity. They further mentioned that more detailed studies are needed to determine which parameters are the most strongly related to the erodibilities of tropical soils. Holzhey and Mausbach (1977) proposed using soil taxonomy for estimating the K value of the Universal Soil-Loss Equation.

III. EXPERIMENTAL METHODS

Determination of Soil Erodibility by Using the Nomograph

Selection of Soil Samples

Twenty-eight sites representing seven soil series were studied in this investigation (Table 1). These soils were grouped into four soil management groups (1.5, 2.5, 3/5, and 4) which have been described by Mokma et al. (1974) and were located in Clinton, Ionia, Kalamazoo, Lapeer, Livingston, and Washtenaw counties. Soil series included Boyer, Fox, Kalamazoo, Miami, Morley and Oshtemo. These soils were selected to represent the range of soils where erosion is most likely to be a problem and extensive areas of these soils are being farmed in Michigan. Soil samples were collected in the fall of 1975 except at Livingston county where samples were collected in the spring of 1976. Detailed description of the location of each soil sample is given in Table 2. These soils were collected in clean brown paper bags and prepared according to the standard method described by the U.S.D.A. Soil Conservation Service (1972).

Table 1. Description of selected Michigan soils used in the determination of erodibility

Site No.	Soil Series	County	Surface Soil Texture	Soil Management Group
1	Morley	Lapeer	loam	1.5a
2	Morley	Lapeer	loam	1.5a
3	Morley	Lapeer	loam	1.5a
4	Morley	Washtenaw	loam	1.5a
5	Morley	Washtenaw	loam	1.5a
6	Nester	Muskegon	loam	1.5a
7	Miami	Clinton	loam	2.5a
8	Miami	Clinton	loam	2.5a
9	Miami	Lapeer	loam	2.5a
10	Miami	Lapeer	loam	2.5a
11	Miami	Lapeer	loam	2.5a
12	Miami	Lapeer	loam	2.5a
13	Miami	Lapeer	sandy loam	2.5a
14	Miami	Livingston	loam	2.5a
15	Miami	Washtenaw	loam	2.5a
16	Miami	Washtenaw	loam	2.5a
17	Fox	Clinton	sandy loam	3/5a
18	Fox	Clinton	loam	3/5a
19	Fox	Washtenaw	sandy loam	3/5a
20	Fox	Washtenaw	loam	3/5a
21	Kalamazoo	Kalamazoo	loam	3/5a
22	Boyer	Ionia	sandy loam	4a
23	Boyer	Ionia	sandy loam	4a
24	Boyer	Ionia	sandy loam	4a
25	Boyer	Ionia	loamy sand	4a
26	Oshtemo	Kalamazoo	loamy sand	4a
27	Oshtemo	Lapeer	sandy loam	4a
28	Oshtemo	Lapeer	sandy loam	4a

Table 2. Description of location for collecting soil samples

Site No.	Legal Land Description	Township	County	Soil Type	Classification	Present Land Use
22	E.1/2N.E.1/4S.W. 1/4N.E.1/4 Section 11 T.6N. -R.8W.	Boston	Ionia	Boyer sandy loam	Typic HapludalFs, coarse-loamy, mixed, mesic	old clover field
23	W.1/2N.W.1/4S.E. 1/4N.E.1/4 Section 11 T.6N. -R.8W.	Boston	Ionia	Boyer sandy loam	Typic HapludalFs, coarse-loamy, mixed, mesic	grass field
24	E.1/2N.E.1/4S.E. 1/4S.E.1/4 Section 1 T.6N. -R.8W.	Boston	Ionia	Boyer sandy loam	Typic HapludalFs, coarse-loamy, mixed, mesic	alfalfa field
25	S.E.1/4N.E.1/4S.E. 1/4S.W.1/4 Section 32 T.6-7N. -R.7W.	Easton	Ionia	Boyer loamy sand	Typic HapludalFs, coarse-loamy, mixed, mesic	grass field
17	N.1/2N.W.1/4N.W. 1/4N.W.1/4	Bath	Clinton	Fox sandy loam	Typic HapludalFs, fine-loamy over sandy or sandy skeletal, mixed, mesic	grass field

Table 2 (continued)

Site No.	Legal Land Description	Township	County	Soil Type	Classification	Present Land Use
	Section 23 T.5N. -R.2W.					
18	W.1/2N.W.1/4S.E. 1/4N.E.1/4	Bath	Clinton	Fox loam	Typic HapludalFs, fine-loamy over sandy or sandy skeletal, mixed mesic	corn field
	Section 15 T.5N. -R.2W.					
19	E.1/2N.E.1/4S.E. 1/4N.E.1/4	Lodi	Washtenaw	Fox sandy loam	Typic HapludalFs, fine-loamy over sandy or sandy skeletal, mixed mesic	small grain field
	Section 6 T.3S. -R.5E.					
20	W.1/2N.W.1/4S.W. 1/4N.E.1/4	Lodi	Washtenaw	Fox loam	Typic HapludalFs, fine-loamy over sandy or sandy skeletal, mixed, mesic	corn field
	Section 7T.3S. -R.5E.					
21	W.1/2N.W.1/4S.E. 1/4N.W.1/4	Ross	Kalamazoo	Kalamazoo loam	Typic HapludalFs, fine-loamy, mixed, mesic	corn field
	Section 9T.1S. -R.9W.					

Table 2 (continued)

Site No.	Legal Land Description	Township	County	Soil Type	Classification	Present Land Use
7	W.1/2S.W.1/4S.E. 1/4S.W.1/4N.W.1/4 Section 19 T.5N. -R.1W.	Bath	Clinton	Miami loam	Typic Hapludalfs, fine-loamy, mixed, mesic	corn field
8	N.1/2N.E.1/4N.E. 1/4N.W.1/4S.W.1/4 Section 19 T.5N. -R.1W.	Bath	Clinton	Miami loam	Typic Hapludalfs, fine loamy, mixed, mesic	corn field
9	N.1/2N.W.1/4S.E. 1/4N.W.1/4 Section 30 T.7N. -R.9E.	Elba	Lapeer	Miami loam	Typic Hapludalfs, fine loamy, mixed mesic	alfalfa field
10	N.1/2N.W.1/4S.E. N.W.1/4 Section 30 T.7N. -R.9E.	Elba	Lapeer	Miami loam	Typic Hapludalfs, fine loamy, mixed, mesic	alfalfa field
11	W.1/2S.W.1/4N.E. 1/4N.W.1/4 Section 30 T.7N. -R.9E.	Elba	Lapeer	Miami loam	Typic Hapludalfs, fine loamy, mixed, mesic	small grain field

Table 2 (continued)

Site No.	Legal Land Description	Township	County	Soil Type	Classification	Present Land Use
12	N.1/2N.E.1/4N.W. 1/4S.E.1/4 Section 19 T.7N. -R.9E.	Elba	Lapeer	Miami sandy loam	Typic HapludalFs, fine loamy, mixed, mesic	sorghum field
13	S.1/2S.E.1/4S.W. 1/4N.E.1/4 Section 19 T.7N. -R.9E.	Elba	Lapeer	Miami loam	Typic HapludalFs, fine loamy, mixed, mesic	wheat field
14	S.1/2N.E.1/4N.E. 1/4N.W.1/4 Section 17 T.4N. -R.6E.	Tyrone	Livingston	Miami loam	Typic HapludalFs, fine loamy, mixed, mesic	corn field
15	S.1/2S.E.1/4N.E. 1/4N.E.1/4 Section 14 T.2S. -R.4E.	Lima	Washtenaw	Miami loam	Typic HapludalFs, fine loamy, mixed, mesic	corn field
16	E.1/2N.E.1/4N.E. 1/4S.E.1/4 Section 15 T.2S. -R.4E.	Lima	Washtenaw	Miami loam	Typic HapludalFs fine loamy, mixed, mesic	alfalfa field

Table 2 (continued)

Site No.	Legal Land Description	Township	County	Soil Type	Classification	Present Land Use
1	E.1/2N.E.1/4S.E. 1/4N.W.1/4 Section 33 T.7N. -R.9E.	Elba	Lapeer	Morley loam	Typic Hapludalfs, fine, illitic, mesic	corn field
2	E.1/2N.E.1/4S.E. 1/4N.W.1/4 Section 33 T.7N. -R.9E.	Elba	Lapeer	Morley loam	Typic Hapludalfs, fine, illitic, mesic	corn field
3	S.1/2S.W.1/4S.W. 1/4S.E.1/4 Section 28 T.7N. -R.9E.	Elba	Lapeer	Morley loam	Typic Hapludalfs, fine, illitic, mesic	corn field
4	E.1/2S.E.1/4N.E. 1/4N.E.1/4 Section 28 T.1S. -R.7E.	Salem	Washtenaw	Morley loam	Typic Hapludalfs, fine, illitic, mesic	alfalfa field
5	N.1/2S.W.1/4N.E. 1/4S.W.1/4 Section 27 T.1S. -R.7E.	Salem	Washtenaw	Morley loam	Typic Hapludalfs, fine, illitic, mesic	corn field

Table 2 (continued)

Site No.	Legal Land Description	Township	County	Soil Type	Classification	Present Land Use
6	S.E.1/4S.E.1/4S.E. 1/4S.E.1/4 Section 13 T.10N. -R.13W.	Casnovia	Muskegon	Nester loam	Typic HapludalFs, fine, mixed, mesic	old erosion plots
26	S.E.1/4S.W.1/4S.E. 1/4S.E.1/4 Section 8 T.1S. -R.9W.	Ross	Kalamazoo	Oshtemo loamy sand	Typic HapludalFs, coarse-loamy, mixed, mesic	erosion plots
27	N.1/2S.E.1/4S.E. 1/4S.E.1/4 Section 22 T.6N. -R.12E.	Almont	Lapeer	Oshtemo sandy loam	Typic HapludalFs, coarse-loamy, mixed, mesic	corn field
28	N.1/2S.E.1/4S.E. 1/4S.E.1/4 Section 22 T.6N. -R.12E.	Almont	Lapeer	Oshtemo sandy loam	Typic HapludalFs, coarse-loamy, mixed, mesic	corn field

Collection of Samples

Sites were selected using soil maps of the various counties. Five samples were collected at each site except at Tri-County runoff plots, Kalamazoo. A soil probe was used to take soil samples to the depth of six inches from the soil surface. Each sample consists of fifteen to twenty subsamples. Location, date of collection and soil structure were recorded on the paper bag with permanent ink. Each sample was analyzed for particle size distribution and organic matter content.

Five soil samples were collected from an area adjacent to the former erosion plots in Livingston County because a house has been constructed on the site of the former erosion plots. The subsamples for a sample were taken in a line across the slope. The five lines were about 12 feet apart and parallel to each other. Each sample consisted of fifteen subsamples and was collected in a clean plastic pail, mixed well and then transferred into brown paper bags.

Five soil samples were taken from an area adjacent to the former erosion study plots at Muskegon County because a house has been constructed on the site of the former erosion plots. Each sample was collected by using soil probe and composed of fifteen subsamples.

Thirty-five soil samples were collected from the Tri-county runoff plot at Kalamazoo County. Five samples

were taken from each plot by using a soil probe. Each sample was composed of fifteen probes along the length of the plot.

Mechanical Analyses of Soil Samples

The pipette method of particle-size analysis used in this study is described by Kilmer and Alexander (1949) as a sedimentation procedure for inorganic particles which utilizes pipette sampling at controlled depths and time according to Stoke's Law.

Briefly, 10 g of each air dry soil sample (2mm portion) was treated with hydrogen peroxide (6% and 30%) to destroy organic matter. Carbonates and soluble salts were removed by adding 150 ml of 0.5 N HCl, digesting overnight at room temperature, then washing with distilled water through No. 50 filter paper.

Dispersion of the mineral fractions was accomplished by titration with 0.1 N NaOH and measuring the pH of the soil suspension up to the end point of 8.3 (Jackson, 1958). The soil samples were then agitated for 24 hours in the mechanical shaker.

A sieving procedure for segregating particles coarser than 0.05 mm was accomplished through a 300-mesh sieve into a 1000 ml sedimentation cylinder. In order to separate silt and clay fractions, samples of $< 50 \mu$,

$< 20 \mu$, and $< 2 \mu$ were taken out of the sedimentation cylinder by pipette at controlled depths and times according to Stokes' Law.

The sand fractionation was accomplished by using a series of sieves in a mechanical shaker. Each soil sample was analyzed in duplicate.

Determination of Organic Matter Content

Organic carbon in soil was determined by the chromic acid titration method (Walkley and Black, 1934; Walkley, 1935, 1947). In this method, 1 g of soil (80-mesh) was weighed into a 500 ml erlenmeyer flask. Ten ml of 1 N $K_2Cr_2O_7$ was added, followed by 20 ml of concentrated H_2SO_4 . The mixture was allowed to stand for 30 minutes to cool. Then 200 ml of distilled water were added. After the sample was filtered, 10 ml of H_3PO_4 , 0.1 g of NaF powder and 2 ml of diphenylamine indicator were added to the filtrate. The mixture was titrated with 1 N $Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$ to a green end point. The amount of organic matter was then obtained by multiplying the percentage of carbon by a factor of 1.724. Each sample was analyzed in triplicate.

Assessment of Permeability

The permeability of the least permeable horizon affects the soil erodibility. The relative permeability classes, rather than precise permeability rates, are

used in the soil erodibility nomograph (Wischmeier et al., 1971). Choudry (1973) demonstrated that the influence of permeability on erodibility in the nomograph is not very great. Therefore, undisturbed samples were not collected for permeability measurements. The permeability class was taken from Schneider and Erickson (1972). Soil may be placed into relative permeability classes through the study of structure, texture, porosity, cracking, organic matter, and to some extent color of soil. To facilitate the use of permeability in the nomograph, Wischmeier et al. (1971) coded these permeability classes as given below:

<u>Permeability Class</u>	<u>Code</u>
Rapid	1
Moderate to rapid	2
Moderate	3
Slow to moderate	4
Slow	5
Very slow	6

The permeability classes are defined in Appendix F.

Evaluation of Soil Structure

Soil structure can be described in three categories as follows:

- (1) Type (shape and arrangement of peds)
- (2) Class (size of peds)
- (3) Grade (degree of distinctness of peds)

Wischmeier et al. (1971) states that grade does not significantly affect the erodibility which may be due to its dependence upon moisture content and the observer's judgment. Detailed description of type, class and grade of soil structure has been made by the Soil Survey Staff (1951). In order to evaluate structure for use in the erodibility equation, Wischmeier et al. (1971) assigned codes to different structure categories as follows:

<u>Structure Category</u>	<u>Code</u>
Very fine granular	1
Fine granular	2
Medium or coarse granular	3
Blocky, massive or platy	4

These categories do not include all types of structures, such as single grained, nor sizes of blocky and platy structure. However, each soil may be placed in one of these categories by studying its characteristics as described above. Coarse fragments have not been included

in the list; however, the value of erodibility read from the nomograph can be reduced about 10% for soil with stratified subsoil that includes layers of small stone or gravel without a seriously impeding layer above them (Wischmeier et al., 1971). The effect of structure category on erodibility is of about the same magnitude for permeability as mentioned earlier. The assessment of soil structure in this study was made at the time soil samples were collected in the field. Type and class of soil structure are given in Appendix G.

Determination of Soil Erodibility from Measuring Soil Loss under Field Conditions

This procedure is divided into two types of estimation: the first from former erosion plots and the second from existing plots.

The Use of Records of Soil Loss Data from Former Erosion Plots

Two former erosion plots were used in this study. The first erosion plot was located at the Burton Street Farm, Fenton, Livingston County and the second plot was located at the Ivan Emeric Farm, Casnovia, Muskegon County.

Fenton erosion study plots.--These plots were operated by Fenton and Southeast Livingston Soil Conservation Districts between 1939 and 1945. The plots were

established on Miami loam soil with seven percent slope. The six plots each occupied an area of 1/100 acre (72'3" long by 6' wide). At the lower end of each plot was a concrete catchment basin for collecting runoff and soil loss. An outlet for draining off the excess water was provided in order that the eroded soil could be collected, weighed and sampled. The plots were located in an open area with a westerly exposure. A diagram showing the layout of the plots and catchment basins in these studies is presented in Figure 1.

The cropping and tillage systems on the six plots were as follows:

Plot 1. Up and down cultivation

Rotation: alfalfa, corn, oats, oats, red
clover, corn, oats, hay (R-O-M)

Plot 2. Up and down cultivation

Rotation: alfalfa, alfalfa, corn, corn,
oats, clover-timothy, corn, oats
(R-O-M)

Plot 3. Contour cultivation

Rotation: oats fallow alfalfa, alfalfa,
alfalfa (Sm Br)*, corn, oats,
clover-timothy, corn, oats (R-O-M)

*Smooth Brome

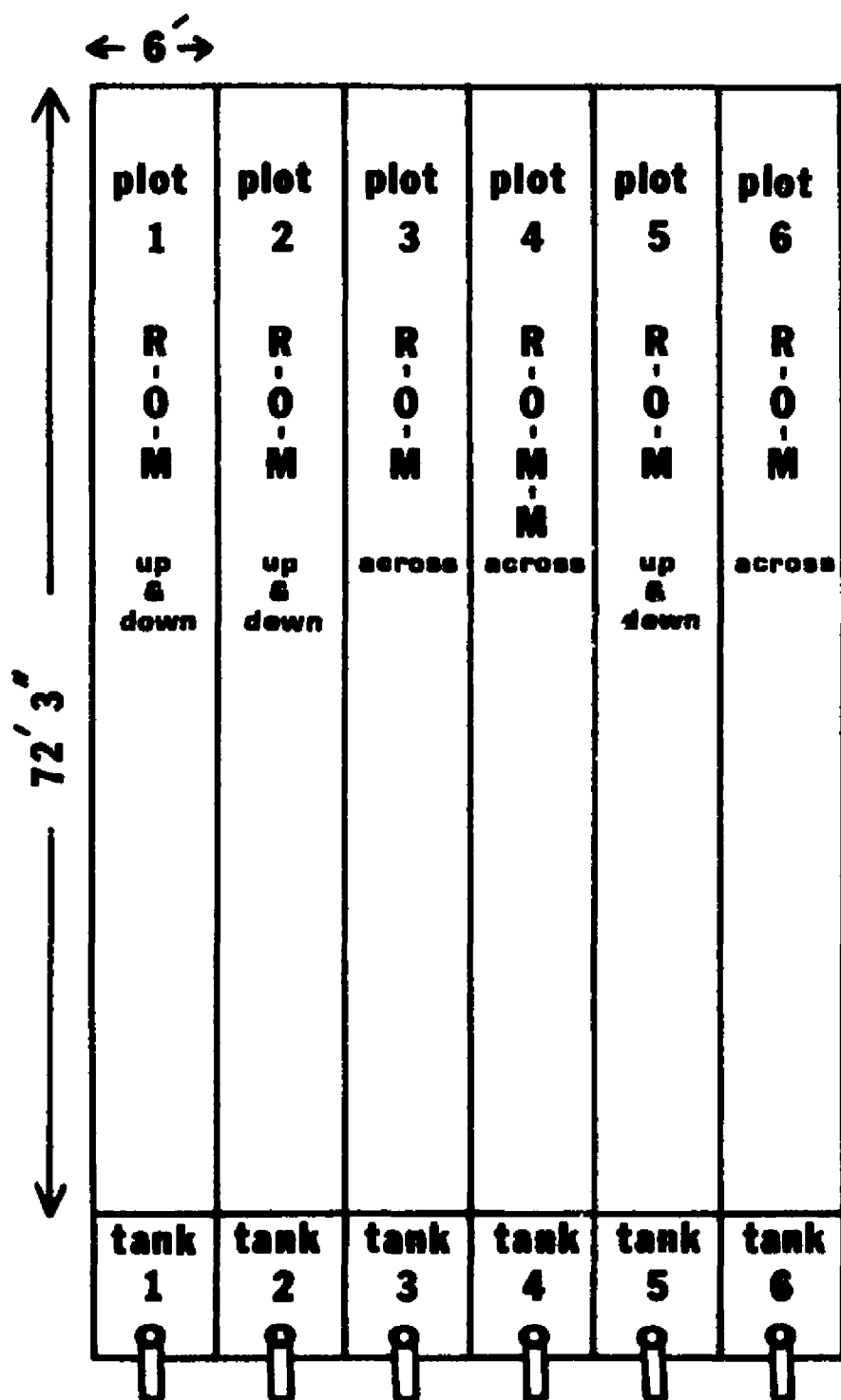


Figure 1. Diagram showing layout of plots and location of catchment basins at Burton Street Farm, Fenton

Plot 4. Contour cultivation

Rotation: corn fallow alfalfa, oats,
alfalfa (Sm Br)*, red clover
(Sm Br)*, corn, oats, hay
(R-O-M-M)

Plot 5. Up and down cultivation

Rotation: corn, corn, oats, red clover-
timothy, corn, oats, hay, corn
(R-O-M)

Plot 6. Contour cultivation

Rotation: corn, oats, alfalfa, corn, oats,
hay, corn (R-O-M)

Soil loss from each plot was measured annually.

Ivan Emeric Farm, Casnovia, Muskegon.--The erosion study plots were carried out by the South Muskegon Soil Conservation District between 1943 and 1963. The plots were located on Nester loam with a 6% slope. The six plots were 72'3" long by 6' wide, an area of 1/100 acre. At the lower end of each plot was a concrete catchment basin for collecting runoff and soil loss. Each basin had an outlet for draining off the excess water in order that the eroded soil could be collected, weighed and sampled. The plots were located in an open

*Smooth Brome

area with westerly exposure. The diagram showing the layout of the plots and catchment basin is shown in Figure 2. The crop sequences and tillage systems were as follows:

- Plot 1. Up and down cultivation
Rotation: continuous corn (R)
- Plot 2. Contour tillage
Rotation: continuous corn (R)
- Plot 3. Contour cultivation
Rotation: corn, oats, hay, hay (R-O-M-M)
- Plot 4. Contour strip cropping
Rotation: corn, oats, hay, hay (R-O-M-M)
- Plot 5. Contour cultivation
Rotation: continuous oats (small grain
annually broadcast) (O)
- Plot 6. Contour cultivation
Rotation: permanent meadow (M)

Soil loss from each plot was measured annually.

Determination of Actual Soil Loss

Tri-County run-off plots.--The plots have been operated and maintained by the Barry, Calhoun, and Kalamazoo Soil Conservation Districts since 1954. They are the only plots still operating in Michigan. The plots are located on the south side of the W. K. Kellogg Biological Station on C Avenue east of Gull Lake in Ross Township, Kalamazoo County.

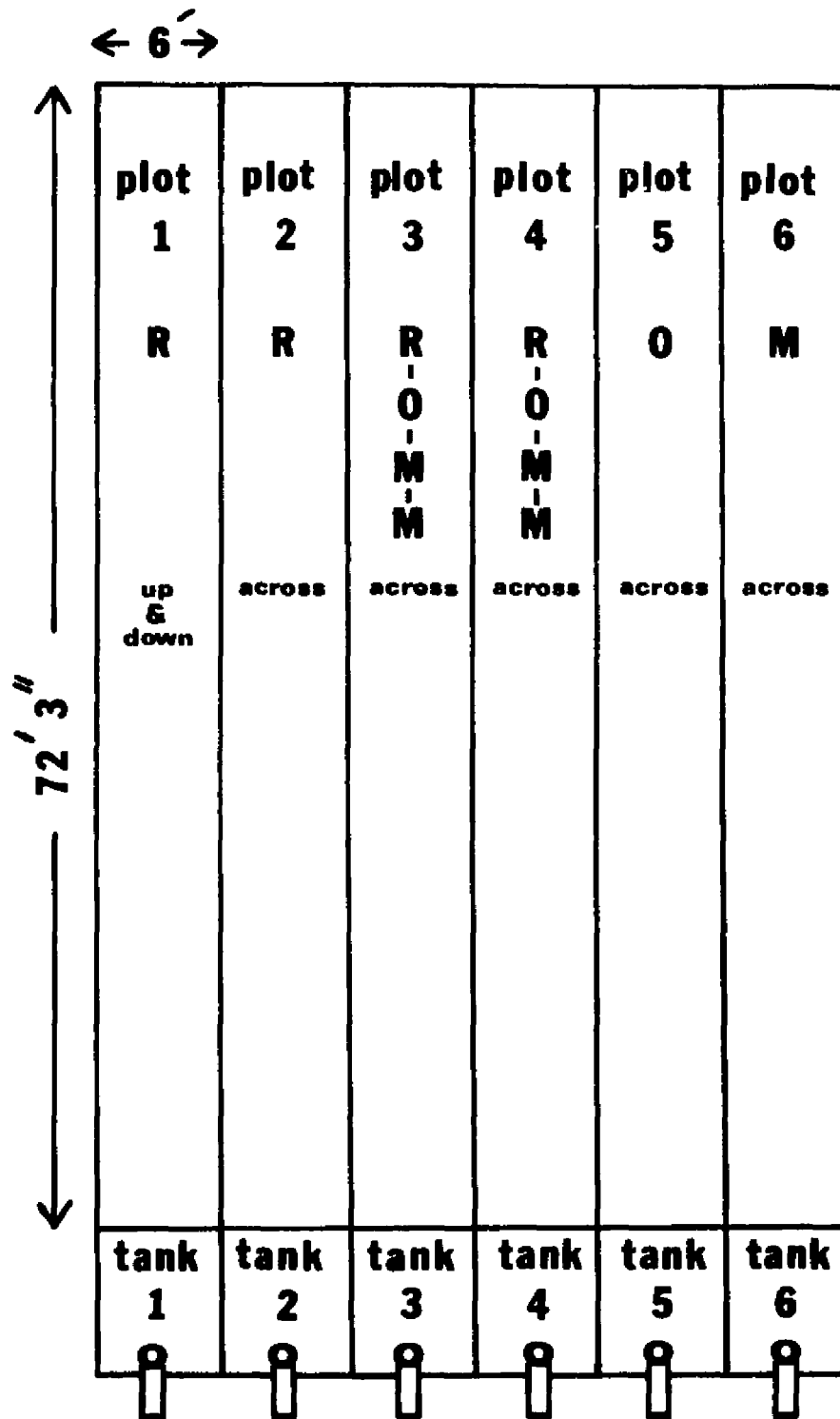


Figure 2. Diagram showing layout of plots and location of catchment basins at Ivan Emeric farm, Casnovia

The seven plots are 72' 3" long by 6' wide, or an area of 1/100 acre. The plots were established on Oshtemo sandy loam with 16% slope. The concrete catchment basin is provided at the lower end of each plot for collecting runoff and eroded soil. Each basin is equipped with an outlet for draining off excess water in order that the eroded soil could be collected, weighed and sampled. The plots were located in an open area with an easterly exposure. The diagram showing the layout of the plots and catchment basin for this study is shown in Figures 3 and 4.

The crop sequences and tillage systems in the original rotations (1954 to 1973) were as follows:

Plot 1. Up and down cultivation

Rotation: continuous corn (R)

Plot 2. Contour cultivation

Rotation: corn, oats, wheat, clover
(R-O-W-M)

Plot 3. Up and down tillage

Rotation: corn, oats, wheat, clover
(R-O-W-M)

Plot 4. Up and down cultivation

Rotation: corn, oats, meadow, meadow
(R-O-M-M)

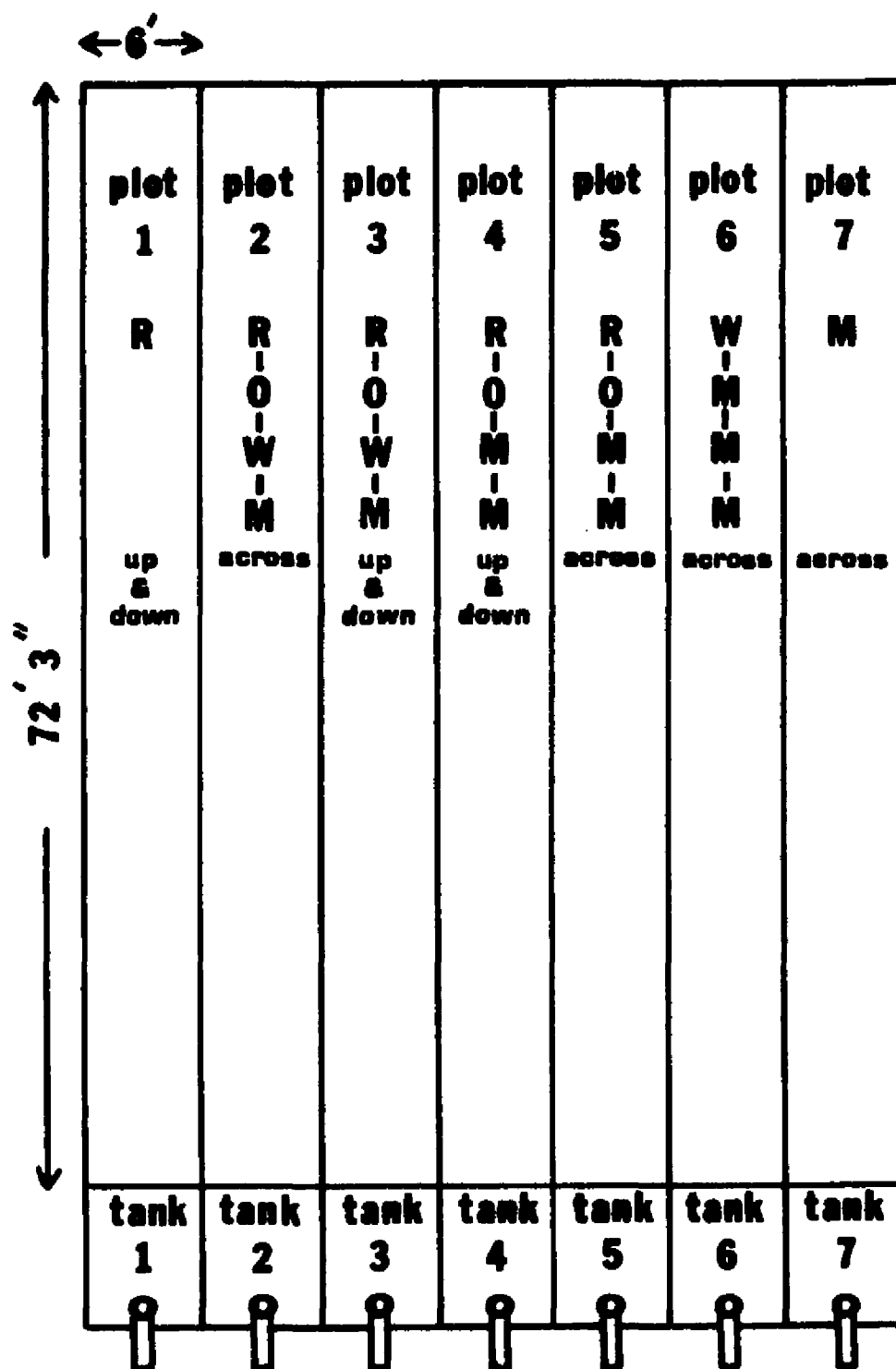


Figure 3. Diagram showing layout of plots and location of catchment basins at Tri-county runoff plot, Kalamazoo (1954-1973)

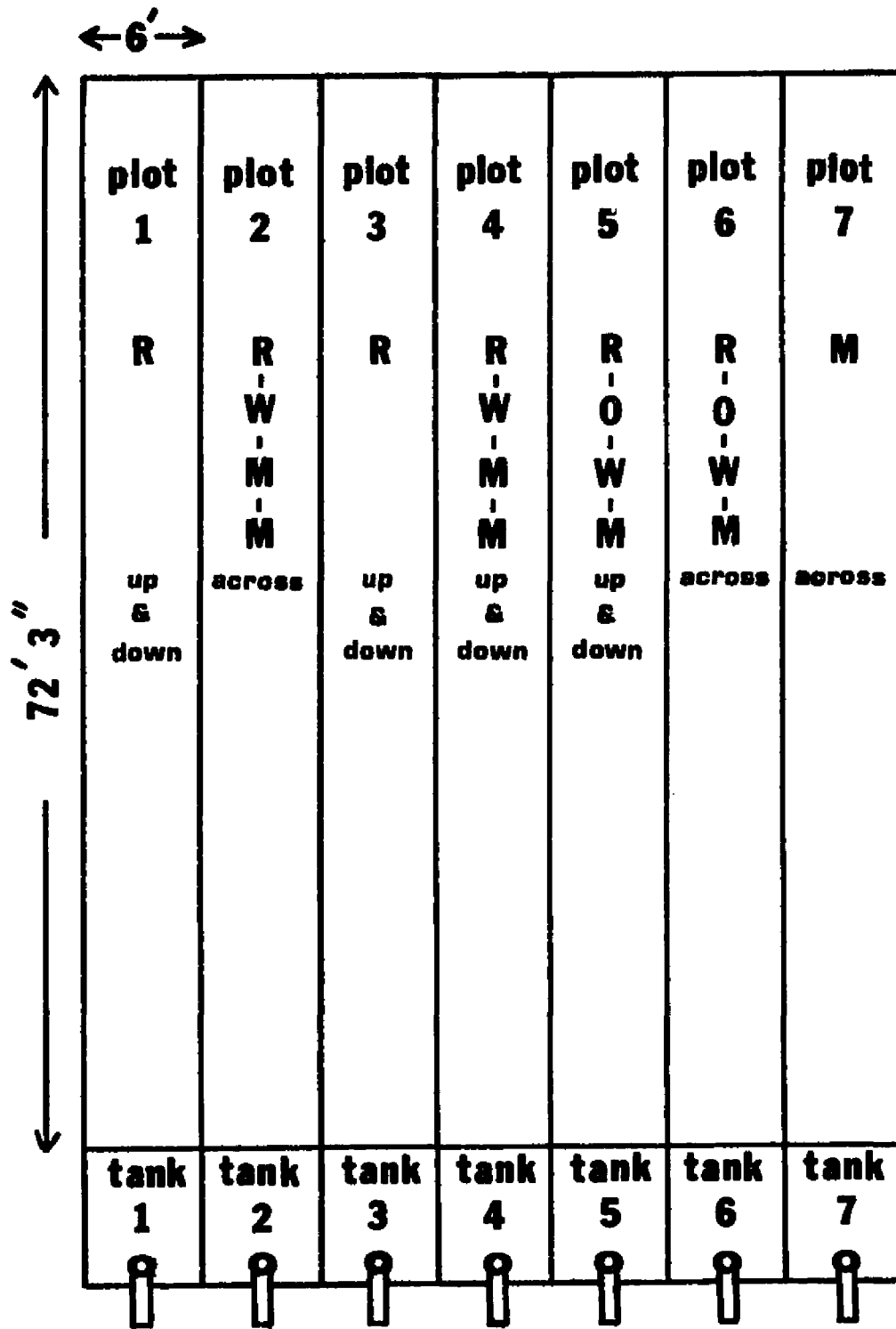


Figure 4. Diagram showing layout of plots and location of catchment basins at Tri-county runoff plot, Kalamazoo (1974-present)

Plot 5. Contour cultivation

Rotation: corn, oats, meadow, meadow
(R-O-M-M)

Plot 6. Rotation: wheat, meadow, meadow, meadow

(W-M-M-M)

Plot 7. Rotation: continuous sod meadow (M)

Soil loss from each plot was measured annually.

New rotations and tillage systems were established in 1974 as follows:

Plot 1. Up and down cultivation and return residues

Rotation: continuous corn (R)

Plot 2. Contour tillage and return residue

Rotation: sorghum, wheat, meadow, meadow
(R-W-M-M)

Plot 3. Up and down cultivation and remove residues

Rotation: continuous corn (R)

Plot 4. Up and down tillage and return residues

Rotation: corn, oats, meadow, meadow
(R-W-M-M)

Plot 5. Up and down cultivation and return residues

Rotation: corn, oats, wheat, clover
(R-O-W-M)

Plot 6. Contour tillage and return residues

Rotation: corn, oats, wheat, clover
(R-O-W-M)

Plot 7. Return residues

Rotation: continuous meadow (M)

Soil loss from each plot was measured annually. During the period September 1975 to June 1977, these plots were part of this study. The cultivation operations were done by hand and/or roto-tiller. Contour tillage was done by hand. The plot was spade 6 inches deep in a line which was across slope direction. This operation was done with the whole plot. Ridges within the row were made at planting time by hoeing the soil to the row. The ridges were enhanced during side dressing of the corn when mixing the fertilizer into the soil.

Detailed cropping operations in 1975 were as follows:

- Plot 1. Corn was harvested on October 16 and crop residues were left on the plot.
- Plot 2. Wheat and clover were planted on September 10 and sorghum was harvested on October 16. Crop residues were left on the plot.
- Plot 3. Sorghum was harvested on October 16 and crop residues were removed from the plot.
- Plot 4. Corn was harvested on October 16 and crop residues were left on the plot.
- Plot 5. Wheat was harvested on October 16 and crop residues were removed from the plot.
- Plot 6. Barley was broadcasted on October 16.

All tanks were clean on October 9. Sediment in each tank was collected in a plastic pail and weighed. About 500 grams of sediment were taken from each tank for determination of moisture content.

Soil samples from each plot were taken on September 4, 1975.

Detailed cropping operations in 1976 were as follows:

Plot 1. Corn was planted on May 11 and was harvested on September 28. Crop residues were left on the plot.

Plot 2. Wheat was harvested on August 3 and crop residues were left on the plot.

Plot 3. Corn was planted on May 11 and was harvested on September 28. Crop residues were removed from the plot.

Plot 4. Oats were sown on May 18 and were harvested on August 24 when alfalfa was broadcasted. Crop residues were left on the plot.

Plot 5. Clover was broadcasted on April 6 and cut on June 16. Crop residues were removed from the plot.

Plot 6. Barley was harvested on August 3 and crop residues were left on the plot.

Plot 7. Grass and alfalfa were cut and left on the plot on June 16.

All tanks were clean on April 6 and October 6. Sediment in each tank was collected in plastic pails and weighed. About 500 grams of sediment were taken from each tank for determination of moisture content.

Detailed cropping operations in 1977 were as follows:

- Plot 1. Corn was planted on April 29. Cultivation and fertilization were conducted on June 17.
- Plot 2. Clover was cut on June 17 and left on the plot.
- Plot 3. Oats were sown on May 2 and harvested on August 7. Crop residues were removed from the plot.
- Plot 4. Corn was planted on April 29. Cultivation and fertilization were done on June 17.
- Plot 5. Clover was cut on June 17 and crop residues were removed from the plot.
- Plot 6. Clover was broadcasted on May 2.
- Plot 7. Grass and alfalfa were cut and left on the plot on June 17.

All tanks were clean on April 20, 1977 and sediment in each tank was collected and weighed.

Monthly precipitation data for the 23-year period (1954-1976) at Tri-County Runoff Plots are shown in Appendices H and I.

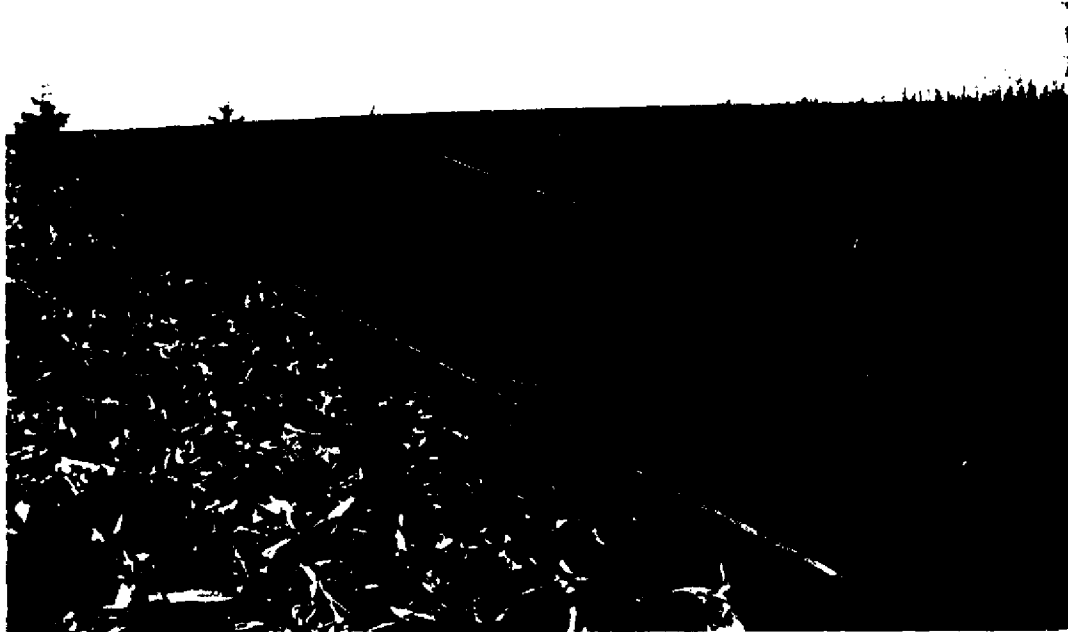


Figure 5. General view of Tri-county runoff plots

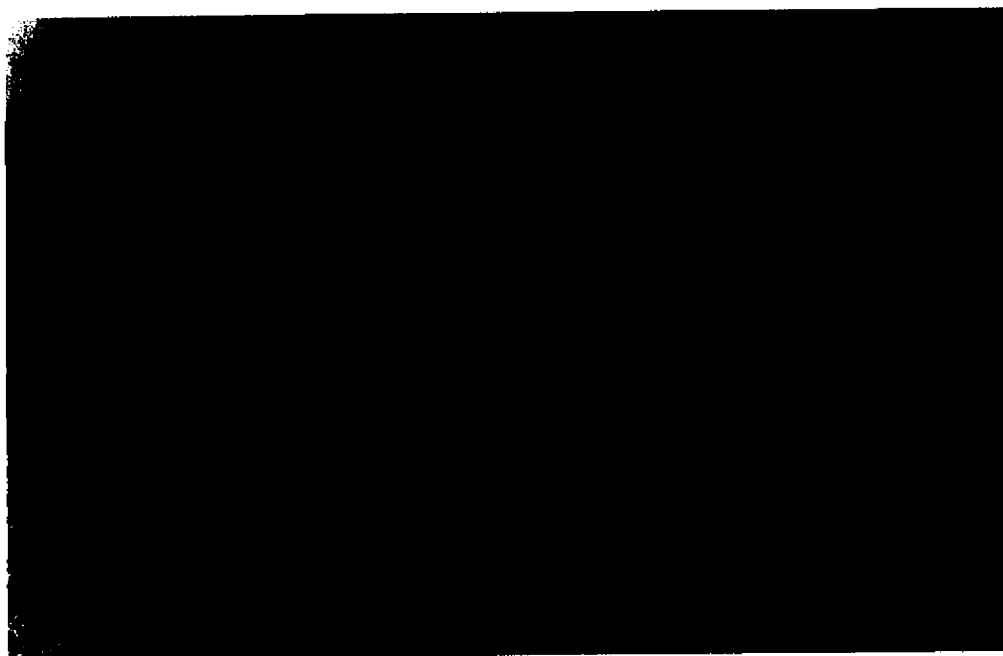


Figure 6. The land slope of the Tri-county runoff plots

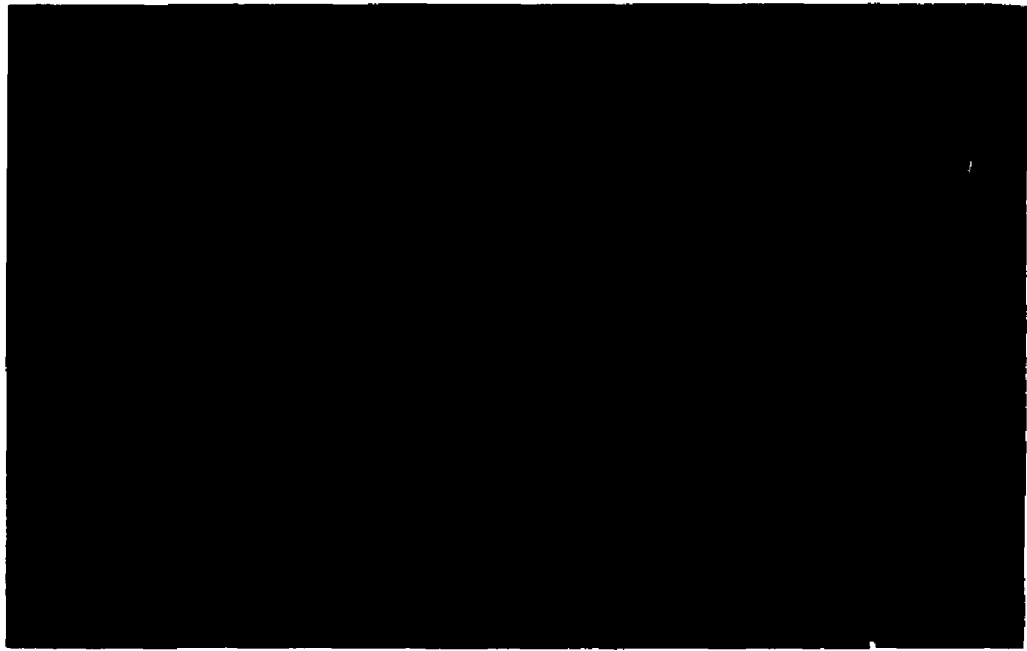


Figure 7. View from upper end to lower end of the plots where collecting tanks are located



Figure 8. Close-up of the concrete catchment basins and barrels for collecting soil loss

Statistical Analysis

The data of soil-loss from the plots located at the three locations were statistically analyzed according to recommendations of Cress (1977). Because the data of soil loss from each plot varied greatly from year to year during the period of study, it is necessary to transform these data by the method described by Gill (1975). The transformed data were analyzed in the design of randomized complete block design as described by Little and Hills (1975).

Simplified Method for Presentation of Soil Loss Data

The graphic technique can be used to simplify the soil-loss data for children and laymen because soil erosion develops many problems for everyone in the community. Wittich and Schuller (1973) defined graphics as materials which communicate facts and ideas clearly and forcibly through a combination of drawings, words, and pictures. The instructional values of graphic materials lie generally in their capacity to attract attention and to convey certain types of information readily. Graphic materials can be divided into six categories which include charts, diagrams, graphs, posters, cartoons, and comics. Among the six categories, graphs are the best way to simplify the soil-loss data. Graphs may be defined as visual representations of the

numerical data. A table or figure may contain a wealth of valuable information, but a graph of the same data presents the gist of that information quickly and effectively. Furthermore, graphs reveal important relationships in the data relationships such as trends and variations from the normal. Most importantly, graphs are inherently more interesting than number tabulations. There are many types of graphs but pictorial statistics are the best. This type of graph is as simple to read as a bar graph and it has the added advantage of using realistic figures to convey meaning. In addition, graphic symbols are easily understood by students at all grade levels and at most levels in intelligence (Kinder, 1959; Brown et al., 1969; Wittich and Schuller, 1973).

Two types of pictorial statistics are used in presenting soil-loss data from the plots which received different management practices.

IV. RESULTS AND DISCUSSION

Mechanical Analysis of Soil Samples

Mechanical analysis by the pipette method was used to determine the percentage of the various particle size fractions. The results of mechanical analyses are shown in Tables 3 and 4. The texture of surface soil horizons of the Morley series, which belongs to soil management group 1.5a, is loam and the Miami series is loam and sandy loam. The Miami series is designated in soil management group 2.5a. Fox and Kalamazoo series are in soil management group 3/5a and their surface textures are loam and sandy loam. Soil management group 4a included the Boyer and Oshtemo series; their soil textures of surface horizon are sandy loam and loamy sand. From the data shown in Table 3 it appears that the variation of particle size distribution within each sampling site of finer texture soils is greater than that of the coarser texture soils and this variation is also greater on cultivated land than pasture land. It is noted that each soil series contains a specific range of the amount of very fine sand, even though they developed at different locations.

Table 3. Particle size distribution and organic matter content of surface horizons from selected soils

Site No.	Soil Series	Sample No.	Particle Size				Textural Class	Organic Matter %
			Coarse Sand %	Very Fine Sand %	Silt %	Clay %		
1	Morley	1	38.15	9.60	36.53	15.72	loam	2.13
		2	34.66	9.47	39.48	16.39	loam	2.41
		3	38.48	9.23	36.05	16.24	loam	1.82
		4	37.96	9.34	34.96	17.74	loam	2.64
		5	41.05	9.43	36.81	12.71	loam	2.21
2	Morley	1	33.28	9.17	36.77	20.78	loam	2.13
		2	37.16	9.52	37.20	16.12	loam	2.94
		3	32.52	9.76	39.18	18.54	loam	2.15
		4	34.71	9.08	40.44	15.77	loam	2.01
		5	32.28	9.33	39.29	19.10	loam	2.24
3	Morley	1	42.13	9.57	32.09	16.21	loam	2.31
		2	44.32	8.45	33.77	13.46	loam	2.44
		3	40.30	9.34	29.93	20.43	loam	2.50
		4	42.99	9.01	32.10	15.90	loam	2.11
		5	45.21	7.72	34.92	12.85	loam	2.62
4	Morley	1	34.29	10.97	36.90	17.84	loam	3.64
		2	36.53	10.09	39.15	14.23	loam	3.45
		3	35.15	10.53	34.89	19.43	loam	2.91
		4	32.54	9.91	38.32	19.23	loam	3.32
		5	34.89	9.86	37.53	17.72	loam	3.55

Table 3 (continued)

Site No.	Soil Series	Sample No.	Particle Size				Textural Class	Organic Matter %
			Coarse Sand %	Very Fine Sand %	Silt %	Clay %		
5	Morley	1	27.96	9.74	43.89	18.41	loam	2.74
		2	24.23	9.14	41.00	25.63	loam	2.21
		3	29.32	9.44	49.73	11.51	loam	2.63
		4	26.18	10.12	45.98	17.72	loam	2.42
		5	25.21	9.97	46.69	18.13	loam	2.54
6	Nester	1	38.27	11.26	38.47	12.00	loam	1.97
		2	28.02	10.50	48.97	12.51	loam	1.95
		3	31.71	10.28	45.22	12.79	loam	1.92
		4	27.24	11.46	49.14	12.16	loam	1.93
		5	31.11	10.82	46.48	11.41	loam	1.94
7	Miami	1	35.48	9.47	42.91	12.14	loam	1.95
		2	33.34	9.99	40.49	16.18	loam	1.81
		3	35.62	9.73	42.74	11.91	loam	2.14
		4	34.31	9.54	43.94	12.21	loam	1.72
		5	37.45	8.32	46.30	7.93	loam	2.18
8	Miami	1	32.93	9.45	42.69	14.93	loam	1.63
		2	35.61	9.67	44.56	10.16	loam	2.11
		3	34.42	9.16	42.21	14.21	loam	1.86
		4	33.35	9.24	42.54	14.87	loam	1.74
		5	30.24	9.79	39.64	20.67	loam	1.66

Table 3 (continued)

Site No.	Soil Series	Sample No.	Particle Size				Textural Class	Organic Matter %
			Coarse Sand %	Very Fine Sand %	Silt %	Clay %		
9	Miami	1	34.50	9.40	38.91	17.19	loam	2.47
		2	31.15	9.67	37.52	21.66	loam	2.61
		3	37.14	9.12	41.10	12.64	loam	2.04
		4	34.49	9.03	38.38	18.10	loam	2.53
		5	35.22	8.92	39.50	16.36	loam	2.25
10	Miami	1	39.57	9.50	37.92	13.01	loam	2.34
		2	41.17	9.17	34.44	15.22	loam	2.51
		3	36.18	9.33	33.04	21.45	loam	2.20
		4	43.05	8.78	37.37	10.80	loam	2.05
		5	40.68	9.41	35.99	13.92	loam	2.25
11	Miami	1	29.46	9.57	44.36	16.61	loam	2.72
		2	28.12	9.02	41.62	21.24	loam	2.41
		3	33.43	8.41	46.30	11.86	loam	2.52
		4	32.09	9.34	42.01	16.56	loam	2.77
		5	31.35	9.45	42.62	16.58	loam	2.83
12	Miami	1	26.06	7.10	43.16	23.68	loam	2.14
		2	30.14	7.84	46.53	15.49	loam	1.78
		3	28.61	7.36	39.97	24.06	loam	1.83
		4	26.57	7.18	43.01	23.24	loam	1.90
		5	25.22	8.06	41.36	25.36	loam	1.95

Table 3 (continued)

Site No.	Soil Series	Sample No.	Particle Size				Textural Class	Organic Matter %
			Coarse Sand %	Very Fine Sand %	Silt %	Clay %		
13	Miami	1	45.99	9.56	29.41	15.04	sandy loam	2.54
		2	44.20	9.81	27.32	18.33	sandy loam	2.42
		3	45.38	9.30	25.82	19.50	sandy loam	2.71
		4	47.50	9.61	28.19	14.70	sandy loam	2.34
		5	52.43	9.05	32.08	6.44	sandy loam	2.24
14	Miami	1	36.14	8.69	42.23	12.94	loam	2.26
		2	41.87	9.31	37.26	11.56	loam	2.27
		3	43.47	8.50	36.27	11.76	loam	2.29
		4	41.72	8.36	38.96	10.96	loam	2.30
		5	44.23	8.71	34.09	12.97	loam	2.25
15	Miami	1	30.69	8.34	45.88	15.09	loam	1.62
		2	25.64	8.43	41.75	24.17	loam	1.45
		3	33.81	8.92	44.45	12.82	loam	1.91
		4	31.23	8.68	47.46	12.63	loam	1.53
		5	29.43	8.63	46.96	14.98	loam	1.24
16	Miami	1	33.03	8.18	45.93	12.86	loam	2.13
		2	28.72	8.56	41.87	20.85	loam	1.78
		3	36.24	8.82	44.50	10.44	loam	1.95
		4	33.65	8.37	46.16	11.82	loam	2.22
		5	32.71	8.89	46.32	12.08	loam	1.88

Table 3 (continued)

Site No.	Soil Series	Sample No.	Particle Size				Textural Class	Organic Matter %
			Coarse Sand %	Very Fine Sand %	Silt %	Clay %		
17	Fox	1	61.97	7.82	24.37	5.84	sandy loam	2.53
		2	67.23	7.69	21.34	4.74	sandy loam	2.72
		3	59.21	8.09	27.98	4.66	sandy loam	2.41
		4	60.62	7.75	22.40	9.23	sandy loam	2.63
		5	61.11	7.89	24.77	6.23	sandy loam	2.84
18	Fox	1	41.42	8.51	42.44	7.63	loam	1.95
		2	37.17	8.59	38.80	15.44	loam	2.12
		3	41.37	8.92	45.35	8.36	loam	2.64
		4	40.35	8.55	40.87	10.23	loam	2.35
		5	38.14	8.23	38.14	15.49	loam	2.40
19	Fox	1	55.10	7.88	26.19	10.83	sandy loam	2.41
		2	52.16	7.48	31.84	8.52	sandy loam	2.11
		3	60.28	7.81	22.35	9.56	sandy loam	2.24
		4	55.74	7.64	26.06	10.56	sandy loam	2.51
		5	54.07	7.87	24.28	13.78	sandy loam	2.35
20	Fox	1	41.02	8.17	39.00	11.81	loam	2.83
		2	43.73	8.82	40.05	9.95	loam	2.71
		3	41.41	8.04	37.31	13.24	loam	2.14
		4	42.09	8.42	33.67	11.76	loam	2.32
		5	39.55	8.29	36.97	15.19	loam	2.41

Table 3 (continued)

Site No.	Soil Series	Sample No.	Particle Size				Textural Class	Organic Matter %
			Coarse Sand %	Very Fine Sand %	Silt %	Clay %		
21	Kalamazoo	1	36.10	4.73	46.85	12.32	loam	2.29
		2	39.43	4.36	44.72	11.49	loam	2.15
		3	40.09	4.29	46.23	9.39	loam	2.33
		4	38.08	4.64	42.98	14.30	loam	2.40
		5	40.20	4.46	45.59	9.75	loam	2.48
22	Boyer	1	67.32	6.42	21.03	5.23	sandy loam	1.25
		2	69.21	6.03	22.22	6.54	sandy loam	1.52
		3	67.12	6.27	21.84	4.77	sandy loam	1.24
		4	66.21	6.08	20.35	7.36	sandy loam	1.63
		5	67.24	6.52	20.74	5.50	sandy loam	1.26
23	Boyer	1	67.52	6.34	20.56	5.58	sandy loam	1.62
		2	68.13	6.72	21.49	6.66	sandy loam	1.77
		3	67.19	6.64	20.36	5.81	sandy loam	1.95
		4	67.45	6.80	18.52	6.37	sandy loam	1.74
		5	68.31	6.24	21.08	5.46	sandy loam	1.57
24	Boyer	1	65.68	5.55	22.82	5.95	sandy loam	1.64
		2	66.43	5.93	21.29	6.35	sandy loam	1.72
		3	65.46	5.74	23.42	5.38	sandy loam	1.30
		4	66.11	5.92	22.23	5.74	sandy loam	1.51
		5	65.27	5.35	23.05	6.33	sandy loam	1.48

Table 3 (continued)

Site No.	Soil Series	Sample No.	Particle Size				Textural Class	Organic Matter %
			Coarse Sand %	Very Fine Sand %	Silt %	Clay %		
25	Boyer	1	75.02	4.93	15.25	4.80	loamy sand	1.64
		2	76.42	5.14	14.28	4.16	loamy sand	1.42
		3	75.17	5.08	15.05	4.70	loamy sand	1.31
		4	75.48	5.31	13.91	5.30	loamy sand	1.52
		5	75.67	5.42	13.73	5.18	loamy sand	1.71
27	Oshtemo	1	49.17	5.63	34.90	10.30	sandy loam	1.95
		2	50.11	5.26	36.08	8.55	sandy loam	2.13
		3	48.81	5.50	32.73	12.96	sandy loam	2.05
		4	49.04	5.76	33.90	11.30	sandy loam	1.82
		5	50.22	5.45	33.74	10.59	sandy loam	1.90
28	Oshtemo	1	51.45	5.60	36.43	6.52	sandy loam	2.37
		2	50.32	5.13	35.14	9.41	sandy loam	2.17
		3	49.44	5.92	33.96	10.68	sandy loam	2.45
		4	51.51	5.89	35.56	7.04	sandy loam	2.36
		5	48.68	6.03	34.34	10.95	sandy loam	2.40

Table 4. Particle size distribution and organic matter content surface soil at Tri-county runoff plots (site no. 26)

Plot No.	Treatment	Sample No.	Particle Size				Textural Class	Organic Matter %
			Coarse Sand %	Very Fine Sand %	Silt %	Clay %		
1	R (up and down) Return residues	1	77.17	5.52	12.65	4.66	loamy sand	0.85
		2	78.32	4.65	12.79	4.24	loamy sand	0.88
		3	77.94	5.71	11.88	4.47	loamy sand	0.82
		4	77.90	5.38	12.29	4.43	loamy sand	0.82
		5	78.26	5.11	12.16	4.47	loamy sand	0.85
2	R-W-M-M (across) Return residues	1	77.41	4.73	12.31	5.55	loamy sand	1.08
		2	77.60	4.38	12.48	5.54	loamy sand	1.08
		3	77.47	4.67	12.80	5.06	loamy sand	1.10
		4	77.79	4.60	12.24	5.37	loamy sand	1.14
		5	78.23	4.70	11.75	5.32	loamy sand	1.14
3	R (up and down) Remove residues	1	77.86	5.70	11.87	4.57	loamy sand	1.05
		2	76.73	5.77	12.73	4.77	loamy sand	1.05
		3	78.23	5.20	12.29	4.28	loamy sand	1.01
		4	77.49	5.65	12.38	4.48	loamy sand	1.08
		5	77.74	5.48	12.58	4.20	loamy sand	1.05
4	R-W-M-M (up and down) Return residues	1	76.85	5.35	12.35	5.45	loamy sand	1.28
		2	76.27	5.55	12.68	5.50	loamy sand	1.21
		3	76.61	5.35	12.42	5.62	loamy sand	1.20
		4	76.77	5.61	11.89	5.73	loamy sand	1.26
		5	76.56	5.39	12.67	5.38	loamy sand	1.24

Table 4 (continued)

Plot No.	Treatment	Sample No.	Particle Size				Textural Class	Organic Matter %
			Coarse Sand %	Very Fine Sand %	Silt %	Clay %		
5	R-O-W-M (up and down) Remove residues	1	77.15	5.42	11.98	5.45	loamy sand	1.46
		2	76.57	5.45	12.19	5.79	loamy sand	1.49
		3	77.23	5.50	11.84	5.43	loamy sand	1.51
		4	76.67	5.70	12.04	5.59	loamy sand	1.44
		5	76.38	5.65	12.39	5.58	loamy sand	1.40
6	R-O-W-M (across) Return residues	1	76.60	5.65	12.21	5.54	loamy sand	1.58
		2	76.56	5.53	12.30	5.61	loamy sand	1.60
		3	75.87	5.89	12.69	5.55	loamy sand	1.60
		4	76.50	5.67	12.49	5.34	loamy sand	1.63
		5	76.35	5.57	12.54	5.54	loamy sand	1.59
7	M (across) Return residues	1	76.01	5.82	12.54	5.63	loamy sand	1.69
		2	75.11	5.83	13.47	5.59	loamy sand	1.66
		3	75.53	5.41	13.47	5.44	loamy sand	1.67
		4	75.63	5.62	13.11	5.64	loamy sand	1.67
		5	76.27	5.24	13.09	5.40	loamy sand	1.65

Organic Matter

Values for organic matter content of soil samples are given in Tables 3 and 4. Soil series belonging to the soil management group 4a have the lowest amount of organic matter and the soil series designated in soil management group 1.5a have relatively high organic matter. This agrees with the report prepared by Mokma et al. (1976). The variation of soil organic matter with treatment at the Tri-county plots is shown in Table 22 and Figure 13. It is noted that the amount of soil organic matter increases as the number of years row crop decreases. This is due to less soil erosion occurring on those plots. The effects of cultural practices on soil organic matter can be seen from these data. The amount of soil organic matter under plots with contour tillage is higher than plot which had up and down slope cultivation.

Assessment of Soil Permeability

The permeability of soil samples was evaluated as described by Schneider and Erickson (1972) and the U.S.D.A. Soil Survey Manual (1951). The permeability classes of the soil samples are given in Table 5.

Evaluation of Soil Structure

The structure of soil samples was evaluated in the field as described by U.S.D.A. Soil Survey Manual (1951). The descriptions of soil structure are given in Table 5.

Determination of Soil Erodibility (K) by Using Wischmeier's Nomograph

Wischmeier's nomograph (Figure 9) requires five soil parameters including the percentage of silt plus very fine sand, sand (0.1-2.0 mm), organic matter, soil structure and soil permeability. Values for these soil parameters and erodibility of soils are shown in Tables 6 to 10. The range, mean, and standard deviation of soil erodibility (K) for each soil management group and soil series are presented in Tables 11 and 12 and Figures 10 and 11. The variation of K values within site, soil series and soil management group depends primarily on the amount of sand, silt and organic matter content in those soils. It was found that the variation of K values within a sampling site of fine texture soils is greater than that of coarser texture soils.

The erodibility of the Morley series ranges between 0.31 and 0.40.

Table 5. Structure and permeability for selected soil samples

Site No.	Soil Series	Sample No.	Soil Structure	Soil Permeability
1	Morley	1	Gran. Med.	Very Slow
		2	Gran. Med.	Very Slow
		3	Gran. Med.	Very Slow
		4	Gran. Med.	Very Slow
		5	Gran. Med.	Very Slow
2	Morley	1	Gran. Med.	Very Slow
		2	Gran. Med.	Very Slow
		3	Gran. Med.	Very Slow
		4	Gran. Med.	Very Slow
		5	Gran. Med.	Very Slow
3	Morley	1	Gran. Med.	Very Slow
		2	Gran. Med.	Very Slow
		3	Gran. Med.	Very Slow
		4	Gran. Med.	Very Slow
		5	Gran. Med.	Very Slow
4	Morley	1	Gran. Med.	Very Slow
		2	Gran. Med.	Very Slow
		3	Gran. Med.	Very Slow
		4	Gran. Med.	Very Slow
		5	Gran. Med.	Very Slow
5	Morley	1	Gran. Fine	Very Slow
		2	Gran. Fine	Very Slow
		3	Gran. Fine	Very Slow
		4	Gran. Fine	Very Slow
		5	Gran. Fine	Very Slow

Table 5 (continued)

Site No.	Soil Series	Sample No.	Soil Structure	Soil Permeability
6	Nester	1	Gran. Med.	Slow
		2	Gran. Med.	Slow
		3	Gran. Med.	Slow
		4	Gran. Med.	Slow
		5	Gran. Med.	Slow
7	Miami	1	Gran. Med.	Slow
		2	Gran. Med.	Slow
		3	Gran. Med.	Slow
		4	Gran. Med.	Slow
		5	Gran. Med.	Slow
8	Miami	1	Gran. Med.	Slow
		2	Gran. Med.	Slow
		3	Gran. Med.	Slow
		4	Gran. Med.	Slow
		5	Gran. Med.	Slow
9	Miami	1	Gran. Med.	Slow
		2	Gran. Med.	Slow
		3	Gran. Med.	Slow
		4	Gran. Med.	Slow
		5	Gran. Med.	Slow
10	Miami	1	Gran. Med.	Slow
		2	Gran. Med.	Slow
		3	Gran. Med.	Slow
		4	Gran. Med.	Slow
		5	Gran. Med.	Slow

Table 5 (continued)

Site No.	Soil Series	Sample No.	Soil Structure	Soil Permeability
11	Miami	1	Gran. Med.	Slow
		2	Gran. Med.	Slow
		3	Gran. Med.	Slow
		4	Gran. Med.	Slow
		5	Gran. Med.	Slow
12	Miami	1	Gran. Fine	Slow
		2	Gran. Fine	Slow
		3	Gran. Fine	Slow
		4	Gran. Fine	Slow
		5	Gran. Fine	Slow
13	Miami	1	Gran. Fine	Slow
		2	Gran. Fine	Slow
		3	Gran. Fine	Slow
		4	Gran. Fine	Slow
		5	Gran. Fine	Slow
14	Miami	1	Gran. Fine	Slow
		2	Gran. Fine	Slow
		3	Gran. Fine	Slow
		4	Gran. Fine	Slow
		5	Gran. Fine	Slow
15	Miami	1	Gran. Fine	Slow
		2	Gran. Fine	Slow
		3	Gran. Fine	Slow
		4	Gran. Fine	Slow
		5	Gran. Fine	Slow

Table 5 (continued)

Site No.	Soil Series	Sample No.	Soil Structure	Soil Permeability
16	Miami	1	Gran. Fine	Slow
		2	Gran. Fine	Slow
		3	Gran. Fine	Slow
		4	Gran. Fine	Slow
		5	Gran. Fine	Slow
17	Fox	1	Gran. Med.	Slow
		2	Gran. Med.	Slow
		3	Gran. Med.	Slow
		4	Gran. Med.	Slow
		5	Gran. Med.	Slow
18	Fox	1	Gran. Med.	Slow
		2	Gran. Med.	Slow
		3	Gran. Med.	Slow
		4	Gran. Med.	Slow
		5	Gran. Med.	Slow
19	Fox	1	Gran. Fine	Slow
		2	Gran. Fine	Slow
		3	Gran. Fine	Slow
		4	Gran. Fine	Slow
		5	Gran. Fine	Slow
20	Fox	1	Gran. Fine	Slow
		2	Gran. Fine	Slow
		3	Gran. Fine	Slow
		4	Gran. Fine	Slow
		5	Gran. Fine	Slow

Table 5 (continued)

Site No.	Soil Series	Sample No.	Soil Structure	Soil Permeability
21	Kalamazoo	1	Gran. Fine	Slow
		2	Gran. Fine	Slow
		3	Gran. Fine	Slow
		4	Gran. Fine	Slow
		5	Gran. Fine	Slow
22	Boyer	1	Gran. Fine	Rapid
		2	Gran. Fine	Rapid
		3	Gran. Fine	Rapid
		4	Gran. Fine	Rapid
		5	Gran. Fine	Rapid
23	Boyer	1	Gran. Fine	Rapid
		2	Gran. Fine	Rapid
		3	Gran. Fine	Rapid
		4	Gran. Fine	Rapid
		5	Gran. Fine	Rapid
24	Boyer	1	Gran. Fine	Rapid
		2	Gran. Fine	Rapid
		3	Gran. Fine	Rapid
		4	Gran. Fine	Rapid
		5	Gran. Fine	Rapid
25	Boyer	1	Gran. Fine	Rapid
		2	Gran. Fine	Rapid
		3	Gran. Fine	Rapid
		4	Gran. Fine	Rapid
		5	Gran. Fine	Rapid

Table 5 (continued)

Site No.	Soil Series	Sample No.	Soil Structure	Soil Permeability
26	Oshtemo	1	Gran. Fine	Rapid
		2	Gran. Fine	Rapid
		3	Gran. Fine	Rapid
		4	Gran. Fine	Rapid
		5	Gran. Fine	Rapid
		6	Gran. Fine	Rapid
		7	Gran. Fine	Rapid
27	Oshtemo	1	Gran. Fine	Rapid
		2	Gran. Fine	Rapid
		3	Gran. Fine	Rapid
		4	Gran. Fine	Rapid
		5	Gran. Fine	Rapid
28	Oshtemo	1	Gran. Fine	Rapid
		2	Gran. Fine	Rapid
		3	Gran. Fine	Rapid
		4	Gran. Fine	Rapid
		5	Gran. Fine	Rapid

Table 6. Soil properties for determining K-value for soil management group 1.5a

Site No.	Soil Series	Sample No.	Silt + VFS %	Coarse Sand %	Organic Matter %	Structure Code	Permeability Code	K Value	Average K-value Site
1	Morley	1	46	38	2.1	3	6	0.40	0.38
		2	49	35	2.4	3	6	0.38	
		3	45	38	1.8	3	6	0.39	
		4	44	38	2.6	3	6	0.36	
		5	46	41	2.2	3	6	0.38	
2	Morley	1	46	33	2.1	3	6	0.36	0.37
		2	47	37	2.9	3	6	0.38	
		3	48	33	2.1	3	6	0.36	
		4	49	35	2.0	3	6	0.38	
		5	49	32	2.2	3	6	0.38	
3	Morley	1	42	42	2.3	3	6	0.33	0.34
		2	42	44	2.4	3	6	0.345	
		3	39	40	2.5	3	6	0.305	
		4	41	43	2.1	3	6	0.345	
		5	43	45	2.6	3	6	0.355	
4	Morley	1	48	34	3.6	3	6	0.32	0.32
		2	49	37	3.4	3	6	0.33	
		3	45	35	2.9	3	6	0.32	
		4	48	33	3.3	3	6	0.325	
		5	47	35	3.5	3	6	0.32	

Table 6 (continued)

Site No.	Soil Series	Sample No.	Silt + VFS %	Coarse Sand %	Organic Matter %	Structure Code	Permeability Code	K Value	Average K-value Site
5	Morley	1	54	28	2.7	2	6	0.36	0.37
		2	50	24	2.2	2	6	0.33	
		3	59	29	2.6	2	6	0.40	
		4	56	26	2.4	2	6	0.365	
		5	57	25	2.5	2	6	0.375	
6	Nester	1	50	38	2.0	3	5	0.38	0.43
		2	60	28	1.9	3	5	0.44	
		3	55	32	1.9	3	5	0.43	
		4	61	27	1.9	3	5	0.465	
		5	57	31	1.9	3	5	0.44	

K-value for 1.5a = 0.37.

Table 7. Soil properties for determining K-value for soil management group 2.5a

Site No.	Soil Series	Sample No.	Silt + VFS %	Coarse Sand %	Organic Matter %	Structure Code	Permeability Code	K Value	Average K-value Site
7	Miami	1	52	35	1.9	2	5	0.37	0.37
		2	50	33	1.8	2	5	0.355	
		3	52	36	2.1	2	5	0.35	
		4	53	34	1.7	2	5	0.385	
		5	55	37	2.2	2	5	0.395	
8	Miami	1	52	33	1.6	2	5	0.375	0.37
		2	54	36	2.1	2	5	0.38	
		3	51	34	1.9	2	5	0.36	
		4	52	33	1.7	2	5	0.375	
		5	49	30	1.7	2	5	0.34	
9	Miami	1	48	34	2.5	3	5	0.335	0.34
		2	47	31	2.6	3	5	0.31	
		3	50	37	2.0	3	5	0.375	
		4	47	34	2.5	3	5	0.335	
		5	48	35	2.2	3	5	0.34	
10	Miami	1	47	40	2.3	3	5	0.34	0.33
		2	44	41	2.5	3	5	0.32	
		3	42	36	2.2	3	5	0.295	
		4	46	43	2.0	3	5	0.34	
		5	45	41	2.2	3	5	0.335	

Table 7 (continued)

Site No.	Soil Series	Sample No.	Silt + VFS %	Coarse Sand %	Organic Matter %	Structure Code	Permeability Code	K Value	Average K-value Site
11	Miami	1	54	29	2.7	3	5	0.36	0.36
		2	51	28	2.4	3	5	0.33	
		3	55	33	2.5	3	5	0.385	
		4	51	32	2.8	3	5	0.365	
		5	52	31	2.8	3	5	0.35	
12	Miami	1	51	26	2.1	2	5	0.315	0.32
		2	54	30	1.8	2	5	0.385	
		3	47	28	1.8	2	5	0.29	
		4	50	27	1.9	2	5	0.315	
		5	49	25	1.9	2	5	0.295	
13	Miami	1	39	46	2.5	2	5	0.25	0.25
		2	37	44	2.4	2	5	0.24	
		3	35	45	2.7	2	5	0.225	
		4	38	47	2.3	2	5	0.245	
		5	41	52	2.2	2	5	0.30	
14	Miami	1	51	36	2.26	3	5	0.38	0.35
		2	47	42	2.27	3	5	0.36	
		3	45	43	2.29	3	5	0.34	
		4	47	41	2.30	3	5	0.36	
		5	43	44	2.25	3	5	0.33	

Table 7 (continued)

Site No.	Soil Series	Sample No.	Silt + VFS %	Coarse Sand %	Organic Matter %	Structure Code	Permeability Code	K Value	Average K-value Site
15	Miami	1	54	31	1.6	2	5	0.38	0.38
		2	50	26	1.4	2	5	0.32	
		3	53	34	1.9	2	5	0.435	
		4	56	31	1.5	2	5	0.42	
		5	56	29	1.2	2	5	0.415	
16	Miami	1	54	33	2.1	2	5	0.37	0.37
		2	50	29	1.8	2	5	0.33	
		3	53	36	1.9	2	5	0.385	
		4	54	34	2.2	2	5	0.36	
		5	55	33	1.9	2	5	0.395	

K value for 2.5a = 0.34.

Table 8. Soil properties for determining K-values for soil management group 3/5a

Site No.	Soil Series	Sample No.	Silt + VFS %	Coarse Sand %	Organic Matter %	Structure Code	Permeability Code	K Value	Average K-value Site
17	Fox	1	32	62	2.5	3	3	0.24	0.22
		2	29	67	2.7	3	3	0.20	
		3	36	59	2.4	3	3	0.245	
		4	30	61	2.6	3	3	0.20	
		5	33	61	2.8	3	3	0.22	
18	Fox	1	51	41	1.9	3	3	0.375	0.33
		2	47	37	2.1	3	3	0.30	
		3	50	41	2.6	3	3	0.37	
		4	49	40	2.3	3	3	0.335	
		5	46	38	2.4	3	3	0.285	
19	Fox	1	34	55	2.4	2	3	0.19	0.19
		2	39	52	2.1	2	3	0.22	
		3	30	60	2.2	2	3	0.17	
		4	34	56	2.5	2	3	0.185	
		5	32	54	2.3	2	3	0.18	
20	Fox	1	47	41	2.8	2	3	0.275	0.30
		2	46	44	2.7	2	3	0.325	
		3	45	41	2.1	2	3	0.295	
		4	46	42	2.3	2	3	0.305	
		5	45	40	2.4	2	3	0.28	

Table 8 (continued)

Site No.	Soil Series	Sample No.	Silt + VFS %	Coarse Sand %	Organic Matter %	Structure Code	Permeability Code	K Value	Average K-value Site
21	Kalama-zoo	1	52	36	2.3	2	3	0.315	0.30
		2	49	39	2.1	2	3	0.295	
		3	50	40	2.3	2	3	0.31	
		4	48	33	2.4	2	3	0.27	
		5	50	40	2.5	2	3	0.33	

K-value for 3/5a = 0.29

Table 9. Soil properties for determining K-values for soil management group 4a

Site No.	Soil Series	Sample No.	Silt + VFS %	Coarse Sand %	Organic Matter %	Structure Code	Permeability Code	K Value	Average K-value Site
22	Boyer	1	27	67	1.2	2	1	0.13	0.13
		2	28	65	1.5	2	1	0.14	
		3	28	67	1.2	2	1	0.135	
		4	26	66	1.6	2	1	0.12	
		5	27	67	1.3	2	1	0.13	
23	Boyer	1	27	67	1.6	2	1	0.135	0.13
		2	28	65	1.8	2	1	0.14	
		3	27	67	1.9	2	1	0.13	
		4	25	67	1.7	2	1	0.11	
		5	26	68	1.6	2	1	0.14	
24	Boyer	1	28	65	1.64	2	1	0.135	0.13
		2	27	66	1.72	2	1	0.13	
		3	29	65	1.30	2	1	0.14	
		4	28	66	1.51	2	1	0.135	
		5	28	65	1.48	2	1	0.135	
25	Boyer	1	20	75	1.6	2	1	0.075	0.08
		2	19	76	1.6	2	1	0.07	
		3	20	75	1.3	2	1	0.10	
		4	19	75	1.5	2	1	0.07	
		5	19	76	1.7	2	1	0.07	

Table 9 (continued)

Site No.	Soil Series	Sample No.	Silt + VFS %	Coarse Sand %	Organic Matter %	Structure Code	Permeability Code	K Value	Average K-value Site
27	Oshtemo	1	40	49	1.9	2	1	0.19	0.18
		2	41	50	2.1	2	1	0.20	
		3	38	48	2.0	2	1	0.17	
		4	40	49	1.8	2	1	0.17	
		5	39	50	1.9	2	1	0.175	
28	Oshtemo	1	42	51	2.4	2	1	0.20	0.19
		2	40	50	2.2	2	1	0.18	
		3	39	49	2.4	2	1	0.175	
		4	44	51	2.4	2	1	0.20	
		5	40	49	2.4	2	1	0.18	

K-value for 4a = 0.13.

Table 10. Soil properties for determining K-values of Oshtemo at tri-county runoff plots (site no. 26)

Plot No.	Treatment (1954-1973)	Sample	Silt + VFS %	Coarse Sand %	Organic Matter %	Structure Code	Permeability Code	K Value	Average K-value Plot
1	R Up and down	1	18.17	75.77	0.85	2	1	0.09	
		2	17.44	78.38	0.88	2	1	0.08	
		3	17.59	78.47	0.82	2	1	0.085	
		4	17.67	77.39	0.82	2	1	0.085	
		5	17.27	78.24	0.85	2	1	0.08	0.084
2	R-O-W-M Across	1	17.04	77.89	1.08	2	1	0.065	
		2	16.86	77.08	1.08	2	1	0.065	
		3	17.47	77.47	1.10	2	1	0.07	
		4	16.84	78.77	1.14	2	1	0.06	
		5	16.45	78.22	1.14	2	1	0.06	0.064
3	R-O-W-M Up and down	1	17.57	76.85	1.05	2	1	0.065	
		2	18.50	76.73	1.05	2	1	0.075	
		3	17.49	77.22	1.01	2	1	0.07	
		4	18.03	76.97	1.08	2	1	0.075	
		5	18.06	77.74	1.05	2	1	0.065	0.070
4	R-O-M-M Up and down	1	17.70	77.34	1.28	2	1	0.06	
		2	18.23	76.25	1.21	2	1	0.065	
		3	17.77	77.11	1.20	2	1	0.07	
		4	17.50	77.26	1.26	2	1	0.065	
		5	18.06	76.54	1.24	2	1	0.07	0.066

Table 10 (continued)

Plot No.	Treatment (1954-1973)	Sample	Silt + VFS %	Coarse Sand %	Organic Matter %	Structure Code	Permeability Code	K Value	Average K-value Plot
5	R-O-M-M Across	1	17.40	77.59	1.46	2	1	0.065	0.062
		2	17.64	77.48	1.49	2	1	0.065	
		3	17.34	77.35	1.51	2	1	0.06	
		4	17.74	77.03	1.44	2	1	0.06	
		5	18.04	76.38	1.40	2	1	0.06	
6	W-M-M Across	1	17.86	76.77	1.58	2	1	0.065	0.064
		2	17.83	76.18	1.60	2	1	0.06	
		3	18.58	76.09	1.60	2	1	0.065	
		4	18.16	76.67	1.63	2	1	0.065	
		5	18.11	76.01	1.59	2	1	0.065	
7	M Across	1	18.36	74.72	1.69	2	1	0.055	0.061
		2	19.30	74.76	1.66	2	1	0.06	
		3	18.88	75.67	1.67	2	1	0.065	
		4	18.73	75.61	1.67	2	1	0.065	
		5	18.33	76.24	1.65	2	1	0.06	

Average K value Oshtemo = 0.067.

Table 11. Variation of nomograph K-values for surface horizons within soil management groups

Soil Management Group	No. of Sample	Range	Mean	Standard Deviation
1.5a	30	0.31--0.46	0.37	0.041
2.5a	50	0.22--0.43	0.34	0.032
3/5a	25	0.17--0.38	0.27	0.060
4a	37	0.06--0.20	0.13	0.045

Table 12. Variation of nomograph K-value for surface horizons within soil series

Soil Series	No. of Sample	Range	Mean	Standard Deviation
Boyer	20	0.07--0.14	0.12	0.026
Fox	20	0.17--0.38	0.26	0.064
Kalamazoo	5	0.27--0.33	0.30	0.023
Miami	50	0.22--0.43	0.34	0.032
Morley	25	0.31--0.40	0.36	0.028
Nester	5	0.38--0.46	0.43	0.031
Oshtemo	17	0.06--0.20	0.14	0.060

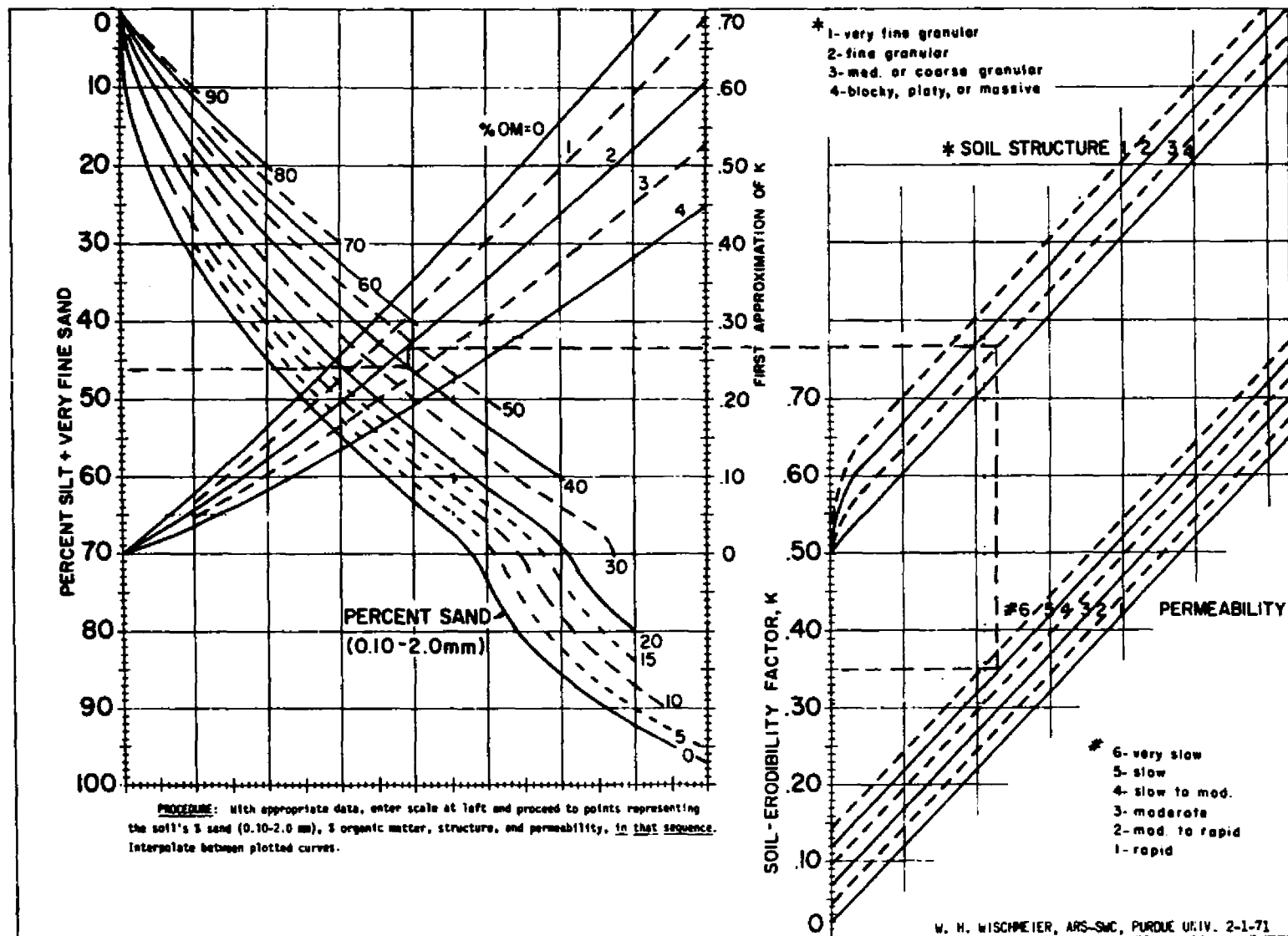


Figure 9. Soil erodibility nomograph (Wischmeier et al., 1971)

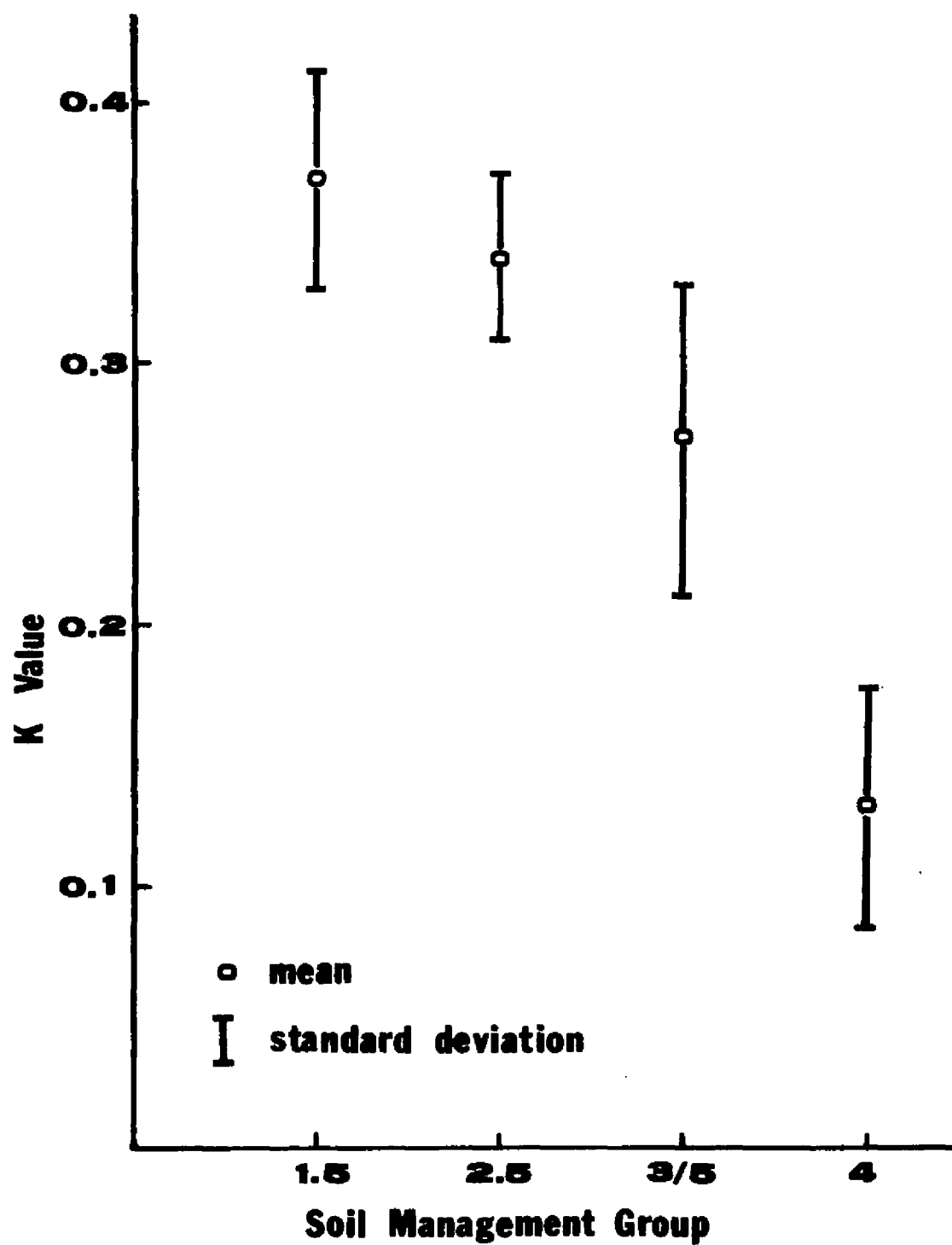


Figure 10. Variation of K values for surface horizon within soil management group

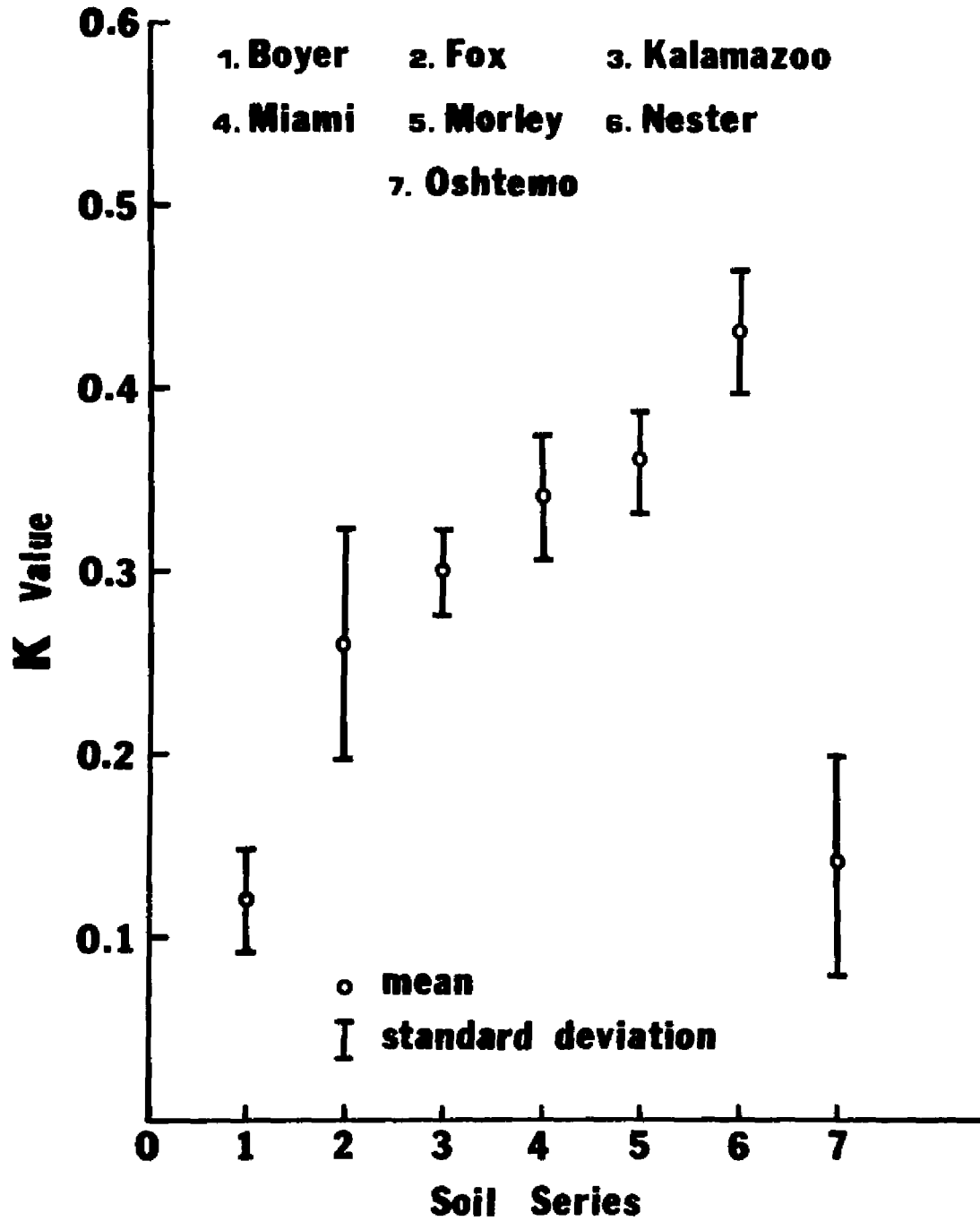


Figure 11. Variation of K values for surface horizon within soil series

The values of soil erodibility of the Nester series range between 0.38 and 0.46. The variation of the K value is due to difference in the amount of sand, silt and organic matter content within this soil. The difference in soil components is due to micro, meso and macrovariability of soil as discussed by James and Dow (1972).

For the Miami series, the K value of this soil varies widely due to the difference in the fine soil parameters. The K value of the Miami series ranges between 0.22 and 0.43. The low value of K results from a soil having higher sand content and the higher value of K results from a soil having higher silt content.

The erodibility of the Fox series ranges between 0.17 and 0.38. The variation of the K value is due to the difference in soil texture and organic matter content within the series.

The values of soil erodibility of Kalamazoo series vary between 0.27 and 0.33. This variation is due to the differences in the amount of sand, silt and organic matter content within this series.

It is found that the variation of K value among soil series is great. The high value of erodibility belongs to that soil having finer texture and the low K value is found in coarser texture.

The variation of soil erodibility of Morley and Nester series appears to be great even though these soils are in the same soil management group. Only one site of Nester soil was sampled. This variation is due to the great difference in the amount of sand, silt and organic matter within both soils.

When these soils are grouped into soil management groups, it is evident that soil management group 1.5a accounts for the highest value of soil erodibility, and soil management group 4a has the lowest value of soil erodibility because soil management group 1.5a contains the highest amount of silt and soil management group 4a has the highest percentage of sand. This agrees with Choudry's work (1973).

Determination of Erodibility Factor (K) by
Measuring Actual Soil Loss under
Field Conditions

The erodibility factor was determined by applying the soil loss values from six plots at Burton Street Farm, Fenton, to the soil loss equation ($K = A/RLSCP$) (Wischmeier and Smith, 1965). The computed K values for Miami soil are shown in Table 13. The computed K values range between 0.04 and 0.54. The average and standard deviation of K value for six plots are 0.31 and 0.19 respectively.

Table 13. K-values obtained from actual soil loss from
Miami loam at Burton Street Farm

Plot No.	Management System	Soil Loss (T/A/Y)	K-value
1	R-O-M (up and down)	2.84	0.30
2	R-O-M (up and down)	4.82	0.52
3	R-O-M (across)	0.21	0.04
4	R-O-M-M (across)	0.86	0.24
5	R-O-M (up and down)	5.03	0.54
6	R-O-M (across)	1.09	0.27
	Average		0.31
	Standard Deviation		0.19

The erodibility for Nester series was computed by applying soil loss values from six plots at Ivan Emeric Farm. The K values from these plots are given in Table 14. The calculated K value falls between 0.043 and 0.34. The average and standard deviation of K value for six plots are 0.19 and 0.11 respectively.

The erodibility factor for Oshtemo series was calculated by applying soil loss values from seven plots at Tri-County Runoff Plots. The K values for these plots are shown in Table 15. The K values for this soil range between 0.024 and 0.054. The average and standard deviation of K value for seven plots are 0.043 and 0.010 respectively.

The K values vary with the amount of soil loss and treatment obtained for each plot. The erodibility factor for soil at Ivan Emeric Farm gives the highest value of standard deviation but the lowest value obtained from Oshtemo series at Tri-County Runoff plots. The possible reasons are that finer texture soil has the greater variation in soil properties and more complicated factors than that of coarse texture soil. Another reason is other factors should be brought to consider in calculation for K values. Those factors suggested by Barnett (1977) are antecedent soil moisture and size of storm.

Table 14. K-values calculated from actual soil loss from Nester loam at Ivan Emeric Farm

Plot No.	Management System	Soil Loss (T/A/Y)	K-value
1	R (up and down)	7.73	0.25
2	R (across)	3.93	0.13
3	R-O-M-M (across)	0.84	0.27
4	R-O-M-M (across-strip)	0.52	0.34
5	O (across)	0.67	0.27
6	M (across)	0.06	0.043
	Average		0.21
	Standard Deviation		0.11

Note. In plots 1, 2, 5 and 6 all residues were removed from the plots. In plots 3 and 4 all residues were returned to the plots.

Table 15. Comparison of K-values obtained from the nomograph and actual soil loss from Oshtemo loamy sand at Tri-county runoff plots

Plot No.	Management System	Nomograph K-value	Actual Soil Loss K-value
1	R (up and down)	0.084	0.048
2	R-O-W-M (across)	0.064	0.046
3	R-O-W-M (up and down)	0.070	0.054
4	R-O-M-M (up and down)	0.066	0.042
5	R-O-M-M (across)	0.062	0.041
6	W-M-M-M (across)	0.064	0.044
7	M (across)	0.061	0.024
	Average	0.067	0.043
	Standard Deviation	0.008	0.009

Comparison of Erodibility Factor
Obtained from Three Methods

Table 16 and Figure 12 show the soil erodibility factor obtained from Wischmeier's nomograph, U.S.D.A. Soil Conservation Service, (U.S.D.A. Soil Conservation Service, 1973), and the computed K value from actual soil loss from erosion study plots. It appears that the K values for the same soil are varied widely among the three methods. The K value established by the U.S.D.A. Soil Conservation Service is higher than K value obtained from actual soil loss. This finding agrees with Barnett's (1977) study. Among three methods, K value established by the U.S.D.A. Soil Conservation Service is the highest but the actual soil loss gives the lowest value for the erodibility factor. The K values obtained from the nomograph are varied within the soil series (Table 12) since the five soil characteristics for the same series are different from one location to another location as described by James and Dow (1972). Apparently, the K value determined by the nomograph may be better than those determined by the other two methods because soil properties of the same soil series are varied at different places. The K value of the same series should not be a constant value at various locations because soil erodibility is affected by chemical, physical properties and management practices. Soils in the same series but located at

Table 16. Average K-values obtained from three methods for different soil series

Soil Series	Soil Management Group	K Nomograph	K USDA Soil Cons. Service	K Actual Soil Loss
Nester	1.5a	0.37	0.43	0.21
Miami	2.5a	0.34	0.37	0.27
Fox	3/5a	0.27	0.32	--
Oshtemo	4a	0.13	0.24	0.043

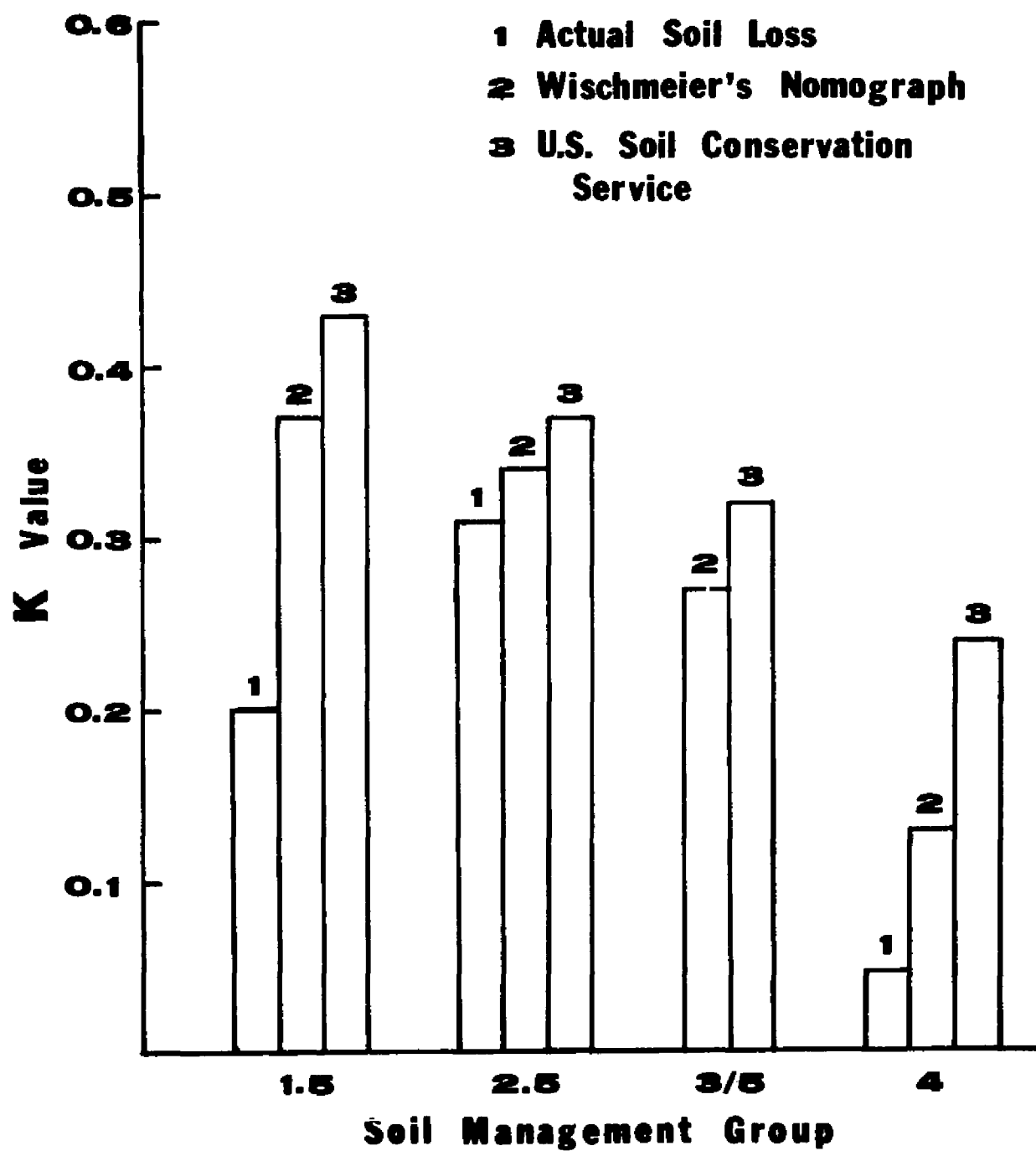


Figure 12. Comparison of K-values obtained from three methods for different soil management groups

different places should have the variation in these properties within the limited range; therefore, the erodibility factor of a soil series or soil management group should have a limited range not only one value for their erodibility factors. This is a confirmation of Tilmann and Mokma (1976) and Holzhey and Mausbash (1977) studies. It is necessary to know the average value of the erodibility factor for each soil series or soil management group. This value can be obtained by a number of determinations of soil erodibility for a given soil series or soil management group at various locations and average them. This value can be used more efficiently in predicting soil loss from each farm and in planning cropping and conservation practices to reduce soil loss to acceptable limits.

Determination of Soil Loss from
Different Cropping and
Cultural Practices

Burton Street Farm, Fenton

Data for soil loss from six plots between 1938 and 1945 (an 8-year period) are given in Table 17 and Figure 13. The annual soil loss data from these plots were statistically analyzed. It appears that soil loss from each plot is significantly different. The plot which received up and down slope cultivation and corn-oats-meadow rotation gives the highest amount of soil loss. By using LSD at 0.05 level it shows that soil

Table 17. Total and average annual soil loss from different cropping and cultural systems for an 8-year period at Burton Street Farm, Fenton (tons/acre/year)

Year	Plot Number						Precipitation (inches)
	I R-O-M (up and down)	II R-O-M (up and down)	III R-O-M (across)	IV R-O-M-M (across)	V R-O-M (up and down)	VI R-O-M (across)	
1 1938	0.22	0.21	0.35	2.30	6.60	tr*	14.01
2 1939	12.89	0.05	0.04	3.40	15.50	0.40	22.60
3 1940	4.34	21.10	0.02	0.02	7.10	2.70	30.99
4 1941	1.13	11.05	0.95	0.35	0.40	0.25	25.85
5 1942	0.03	2.20	0.07	0.01	0.55	1.95	28.65
6 1943	3.95	0.07	0.07	0.70	4.02	2.0	29.22
7 1944	0.10	1.75	0.10	0.07	0.05	0.05	18.45
8 1945	0.10	2.15	0.05	0.05	6.05	1.35	38.28
Total	22.76	38.58	1.65	6.9	40.27	8.70	208.05
Average	2.84	4.82	0.21	0.86	5.03	1.09	27.72

LSD (0.05); 1.99 tons/acre/year

* For statistical computations, trace amounts were considered as 0 tons per acre per year.

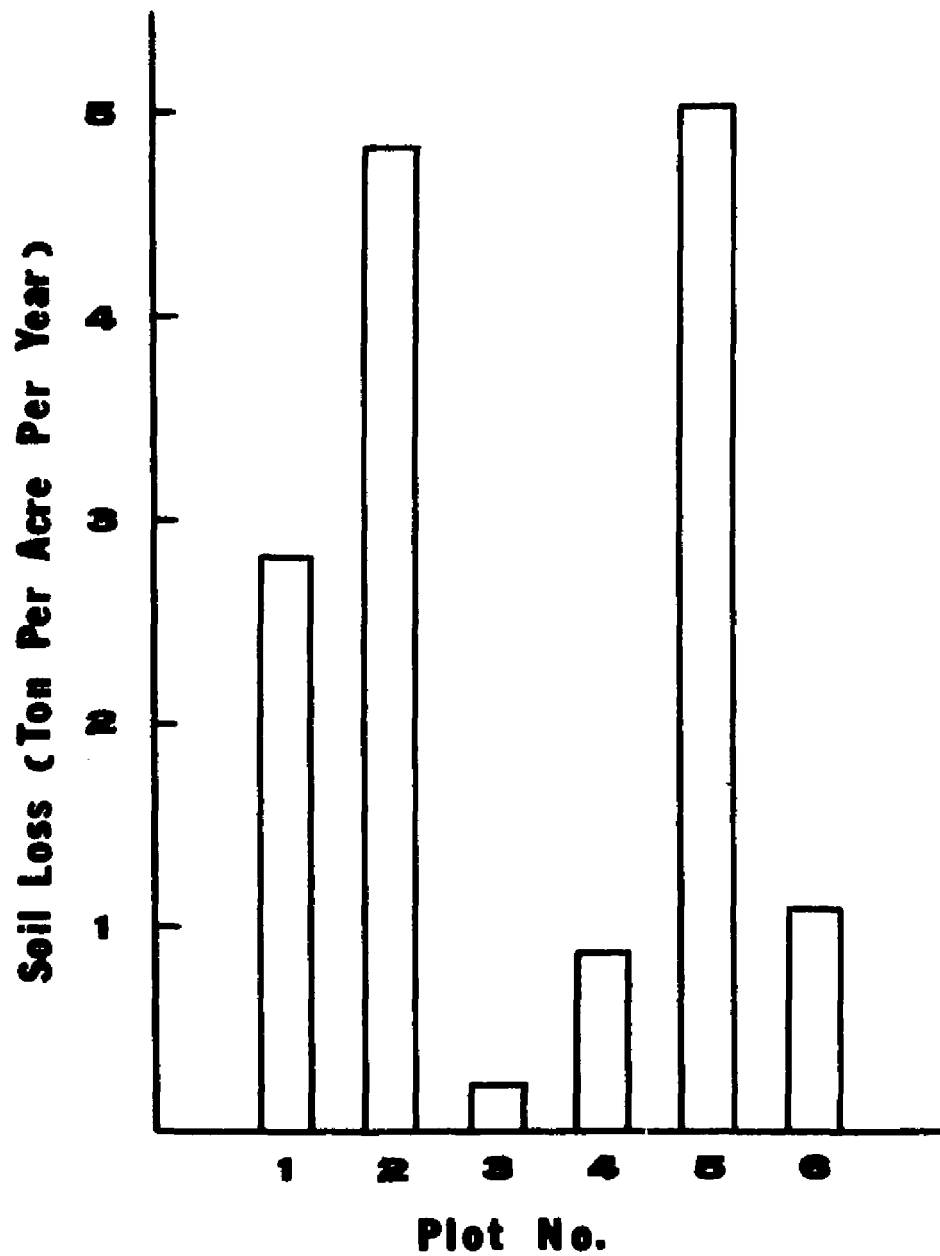


Figure 13. Average annual soil loss from different cropping and cultural systems for an 8-year period at Burton Street Farm, Fenton

loss from plots 2 and 5 are not significantly different, but soil loss from plot 5 is significantly different from plots 1, 3, 4 and 6 because the cropping system for plot 5 consisted of 4 years of corn, 2 years of meadow as compared with other plots which contain fewer years of corn and more years for meadow.

The period of soil exposure to rain for plot 5 is the longest period because the corn crop provides maximum ground cover at mature stage (Wilkinson, 1975) and the most erosive rainstorms in Michigan occur at the early stage of growth of the corn crop. Therefore, soil under plot 5 has a longer period of exposure to rain and wind as compared with other plots. Hudson (1971) suggested that the soil loss from erosion is nearly proportionate to the exposed ground surface. Another reason is that crops other than corn provide better soil conditions for resisting erosion. These conditions may be providing more organic residues on the ground, better soil structure, more absorptive capacity of soil and slow velocity of surface runoff because it has been reported that crops reduce erosion in ways other than by just providing a vegetative canopy against direct raindrop impact (Wilkinson, 1975b).

Plots with rotation systems containing more years of meadow have a longer crop canopy protection period than plots with fewer years of meadow, and

meadow crops provide better soil conditions to resist erosion than row crops such as corn (Duley and Miller, 1923; Miller, 1936; Smith, 1946; Sreenivas et al., 1947; Battawar and Rao, 1969). The lowest amount of soil loss is associated with plot 3 which had a cropping system containing three years meadow, three years of oats (closed growing crop), and two years of corn with contour tillage. The influence of cultivation on soil erosion can be seen in the amount of soil loss from plots 5 and 6 which have the same rotation but different cultivation systems. Up and down slope cultivation was operated on plot 5 but contour cultivation on plot 6. Soil loss from the two plots was significantly different. The amount of soil loss from up and down slope cultivation is 5.03 tons per acre which is much higher than contour cultivation which the amount of soil loss is 1.9 tons per acre. It is noted that the amount of soil loss from plot 5 is approximately 4.6 times as compared with plot 6. This proportion is greatly different from the differences in conservation factors which is 2 for up and down slope and contour cultivation.

Soil loss from plot 1 is significantly different from that of plot 5. Both plots received up and down slope cultivation but a different cropping sequence. Plot 1 had two years of corn, three years of meadow and three years of oats but plot 5 had a cropping system

containing four years of corn, and two years of meadow and two years of oats. The amount of soil loss from plot 1 is 2.84 tons per acre which is less than plot 5 which had a soil loss of 5.03 tons per acre. Soil loss from both plots is different because cropping system on plot 1 contained fewer years of corn and more years of meadow and small grain (oats). Plot 1 has a shorter period of soil exposure to rain and wind and better soil conditions to resist erosion than plot 5. Both plots have the same crop rotation (R-O-M) but difference in cropping sequence.

Ivan Emeric Farm, Muskegon

Total and average annual soil loss from different cropping and cultural system are given in Table 18 and Figure 14.

These data were statistically analyzed and it reveals that the amount of soil loss from each plot is highly significantly different among the six plots. The LSD at 0.05 level for soil loss is 1.25 ton per acre per year. The highest amount of soil loss is associated with plot 1 where corn was grown annually and which received up and down slope cultivation. The reason for this is the soil under this plot has the longest period for exposure to rain, wind and sun as compared with the other five plots. The effective ground cover of corn was negligible for the first weeks of growth

Table 18. Total and average annual soil loss from different cropping and cultural systems for a 20-year period at Ivan Emeric Farm, Muskegon (tons/acre/year)

Year	Plot Number						Precipitation (inches)
	I R (up and down)	II R (across)	III R-O-M-M (across)	IV R-O-M-M (across- strip)	V O (across)	VI M (across)	
1 1944	8.05	7.95	6.95	5.35	tr	tr	27.63
2 1945	4.81	0.85	0.42	0.35	tr	tr	32.84
3 1946	10.80	6.37	0.22	0.32	0.80	tr	28.00
4 1947	15.65	5.60	0.17	0.85	0.65	0.32	29.13
5 1948	4.70	0.85	0.52	0.25	0.40	0.25	23.60
6 1949	15.15	6.20	0.45	0.15	1.20	0.20	32.95
7 1950	13.00	7.45	tr	0.30	1.00	tr	30.75
8 1951	4.00	2.00	tr	tr	tr	tr	33.42
9 1952	6.00	1.30	0.40	tr	tr	tr	27.20
10 1953	4.05	0.05	2.30	tr	tr	tr	24.38
11 1954	9.50	3.30	0.40	2.40	4.20	tr	28.75
12 1955	4.70	3.59	tr	tr	3.30	tr	25.75
13 1956	6.10	4.35	tr	tr	1.10	tr	27.75
14 1957	5.45	2.70	0.60	0.40	0.83	0.35	29.65
15 1958	3.71	2.95	tr	tr	tr	tr	26.40
16 1959	3.40	2.00	tr	tr	tr	tr	36.25
17 1960	8.51	2.95	3.55	0.01	tr	tr	34.10
18 1961	23.00	13.85	0.60	tr	tr	tr	33.50
19 1962	2.55	0.40	0.20	tr	tr	tr	19.00
20 1963	1.50	tr*	tr	tr	tr	tr	27.50
Total	154.63	74.71	16.78	10.38	13.48	1.12	578.5
Average	7.73	3.73	0.84	0.52	0.67	0.06	28.93

LSD (0.05); 1.2543 tons/acre/year

*For statistical computations, trace amounts were considered as 0 tons per acre per year.

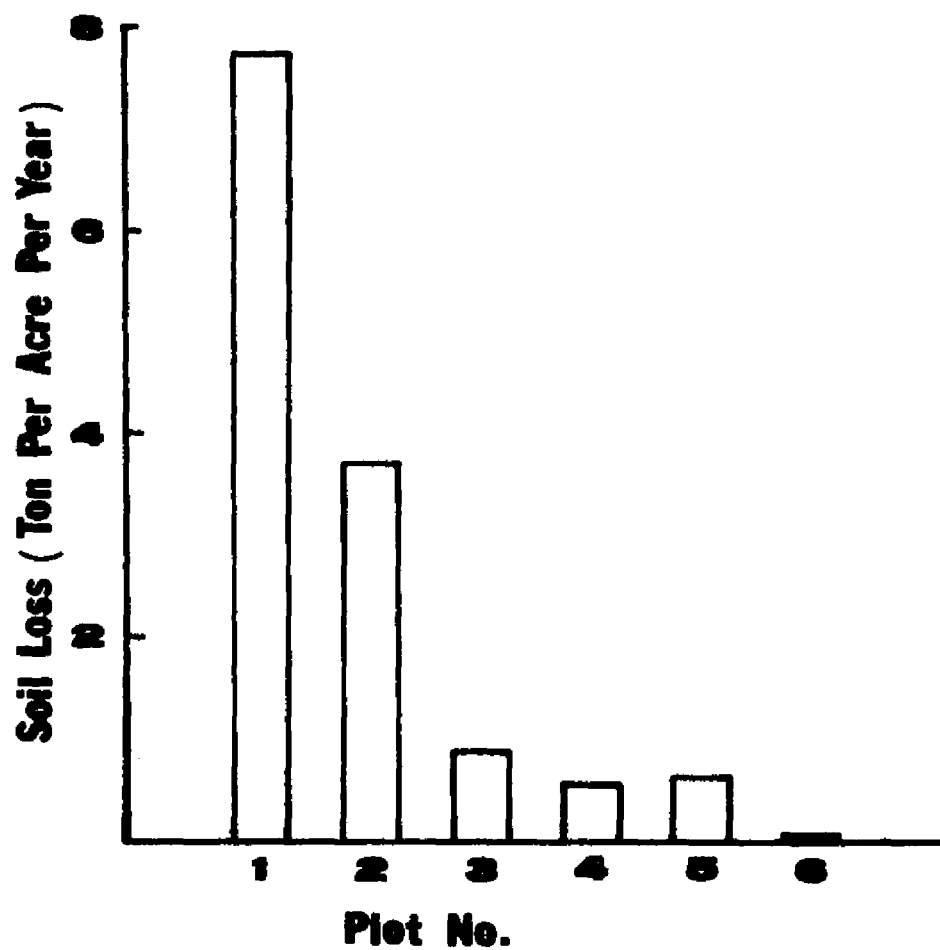


Figure 14. Average annual soil loss from different cropping and cultural systems for 20-year period at Ivan Emeric Farm, Casnovia

and increased rapidly over the next three to four weeks during the period of exponential growth rate of the crop (Wilkinson, 1975b). It has been reported that the most highly erosive rainfall in Michigan occurs during the summer months (Wischmeier and Smith, 1965). At this time the corn crop does not provide maximum ground cover. Therefore, soil has long periods of exposure to erosive rain. Wilkinson (1975b) reported that the interaction of crop season and cultural practices more or less dictates canopy characteristics and soil exposure.

The effect of cultural practices on soil loss can be seen from the amount of soil loss from plots 1 and 2. The amount of soil loss from plots 1 and 2 are 7.73 and 3.73 tons per acre respectively. The contour tillage was performed on plot 2 and up and down slope tillage on plot 1. In both plots corn has been grown annually for a period of 20 years. The amount of soil loss from plot 1 is significantly different from that of plot 2. The conservation factor for up and down slope and contour tillage are 1.0 and 0.5 respectively. The ratio of the amount of soil loss from both plots is about 2. These data agree with given conservation factors.

The effect of cropping systems on soil loss can be observed in the amount of soil loss from plots 2 and 3.

Both plots received contour tillage but have different cropping systems. Corn was grown annually on plot 2, but 4-year rotation of corn-oats-meadow-meadow was operated on plot 3. The value of cropping management factor for continuous corn and the rotation of corn-oats-meadow-meadow are 0.39 and 0.07 respectively. Soil loss from plot 2 is approximately 4.5 times the loss from plot 3. These data are average for a period of 20 years; and, therefore, the value of crop rotation is obvious.

The smallest amount of soil loss is associated with plot 6 which was a permanent meadow. The reason for this is that permanent meadow provides the longest period of effective ground cover and it is a close growing crop, sometimes having a fibrous root system which provides a large amount of crop residues on the ground thereby creating better conditions for resisting erosion (Duley and Miller, 1932; Smith, 1946; Sreenivas et al., 1947).

The effect of different monocropping systems on soil loss can be seen from the amount of soil loss from plots 2 and 5. On plot 2 corn was grown annually and on plot 5 small grain (oats) was annually grown. The amount of soil loss from plots 2 and 5 are 3.73 and 0.67 tons per acre per year. The amount of soil loss from plot 2 is significantly different from that of plot 5. The

reason for this is that a small grain crop provides greater and more effective cover protection than a row crop because small grain is a close-growing crop in nature, provides more organic residues on and under the ground and reduces velocity of surface runoff (Miller, 1936). Small grain provides some effective ground cover during spring season while corn crop is negligible for that period. Soil loss from the continuous corn plot is approximately 5.5 times the loss from continuous small grain.

Plots 3 and 4 have the same crop rotation of corn-oats-meadow but differences in conservation practices. Contour tillage was operated on plot 3 and contour strip cropping on plot 4. The amount of soil loss from plots 3 and 4 are 0.84 and 0.52 tons per acre per year respectively which is not statistically different.

Tri-County Runoff Plots, Kalamazoo

Average annual soil loss and accumulative soil loss from different cropping cultural systems for a 19-year and 3-year period are shown in Tables 19, 20 and 21 and Figures 15 and 16. These data were statistically analyzed.

The original rotation was operated on these plots during that period 1954 and 1973. Soil loss data from these plots during that period are given in Table 19 and

Table 19. Annual average soil loss from different cropping and cultural systems for a 19-acre period (original rotation) at Tri-County Runoff Plots, Kalamazoo (tons/acre/year)

Year	Plot Number							Precipitation (inches)
	I R (up and down)	II R-O-W-M (across)	III R-O-W-M (up and down)	IV R-O-M-M (up and down)	V R-O-M-M (across)	VI W-M-M-M (across)	VII M (across)	
1 1954	21.47	1.27	2.17	0.08	0.08	0.08	0.002	41.53
2 1955	5.20	0.45	0.47	1.24	0.46	0.35	0.50	30.88
3 1956	0.83	0.58	0.39	0.36	0.34	0.08	0.04	23.78
4 1957	11.55	0.90	1.16	0.31	0.45	0.65	0.14	35.51
5 1958	8.37	0.16	0.10	0.09	0.17	0.09	0.09	27.38
6 1959	40.00	16.00	21.00	10.00	12.00	1.00	1.00	34.84
7 1960	36.87	10.00	12.50	3.12	3.75	tr	tr	30.25
8 1961	9.50	2.00	3.75	0.75	0.50	tr	tr	29.85
9 1962	7.00	tr**	1.00	tr	tr	tr	tr	24.49
10 1963	1.50	tr	0.50	0.30	tr	tr	tr	20.71
11 1964	0.04	tr	0.02	tr	tr	tr	0.03	28.71
12 1965	0.13	0.01	0.02	tr	tr	tr	0.01	33.84
13 1966	0.15	0.02	0.03	0.02	tr	tr	tr	36.45
14 1967	0.20	0.03	0.04	0.02	tr	tr	tr	39.64
15 1968	2.62	0.92	1.13	0.18	0.13	0.20	0.01	41.30
16 1969	2.20	0.69	0.75	0.60	1.35	2.55	tr	33.05
17 1970*	-	-	-	-	-	-	-	35.45
18 1971	1.20	0.30	0.40	0.30	0.70	0.30	0.10	33.98
19 1972	2.60	0.70	1.10	0.80	0.70	0.40	0.15	42.29
20 1973	23.75	8.10	8.75	11.25	2.00	1.25	0.90	39.23
Total	175.18	42.13	55.28	29.45	22.63	6.95	2.972	663.16
Average	9.22	2.21	2.91	1.55	1.19	0.37	0.16	34.90

LSD (0.05); 1.23 tons/acre/year

* Soil loss data were not available.

** For statistical computations, trace amounts were considered as 0 tons per acre per year.

Table 20. Average annual soil loss (tons/acre/year) from different cropping and cultural systems at Tri-County Runoff Plots, Kalamazoo

Plot No.	Rotation (Original)	Average Soil Loss 1954-1973	Rotation (New)	Crop 1976	Soil Loss 1976	Average Soil Loss 1974-1976
1	R (up and down)	9.22	R (up and down) Return residues	Corn	0.20	4.06
2	R-O-W-M (across)	2.21	R-W-M-M (across) Return residues	W & A	0.10	1.88
3	R-O-W-M (up and down)	2.91	Continuous Corn (up and down) Remove residues	Corn	0.25	4.16
4	R-O-M-M (up and down)	1.55	R-W-M-M (up and down) Return residues	Oats	tr*	0.40
5	R-O-M-M (across)	1.19	R-O-W-M (up and down) Remove residues	Clover	-	0.21
6	W-M-M-M (across)	0.37	R-O-W-M (across) Return residues	Barley	-	1.04
7	M (across)	0.16	Continuous Meadow (across) Return residues	Meadow	-	0.21

* tr = trace

Table 21. Accumulative and annual soil loss from different cropping and cultural systems for a 3-year period (new rotation) at Tri-County Runoff Plots, Kalamazoo (tons/acre/year)

Year	Plot Number							Precipitation (inches)
	I R (up and down) Return	II R-W-M-M (across) Return	III R (up and down) Remove	IV R-W-M-M (up and down) Return	V R-O-W-M (up and down) Remove	VI R-O-W-M (across) Return	VII M (across) Return	
1 1974	0.19	0.03	0.04	0.03	0.01	tr [*]	tr	34.83
2 1975	11.87	5.50	12.19	1.87	0.62	3.12	0.62	45.83
3 1976	0.20	0.10	0.25	tr	tr	tr	tr	29.93
Total	12.26	5.63	12.48	1.90	0.63	3.12	0.62	110.59
Average	4.09	1.88	4.16	0.63	0.21	1.04	0.21	36.86

* tr = trace

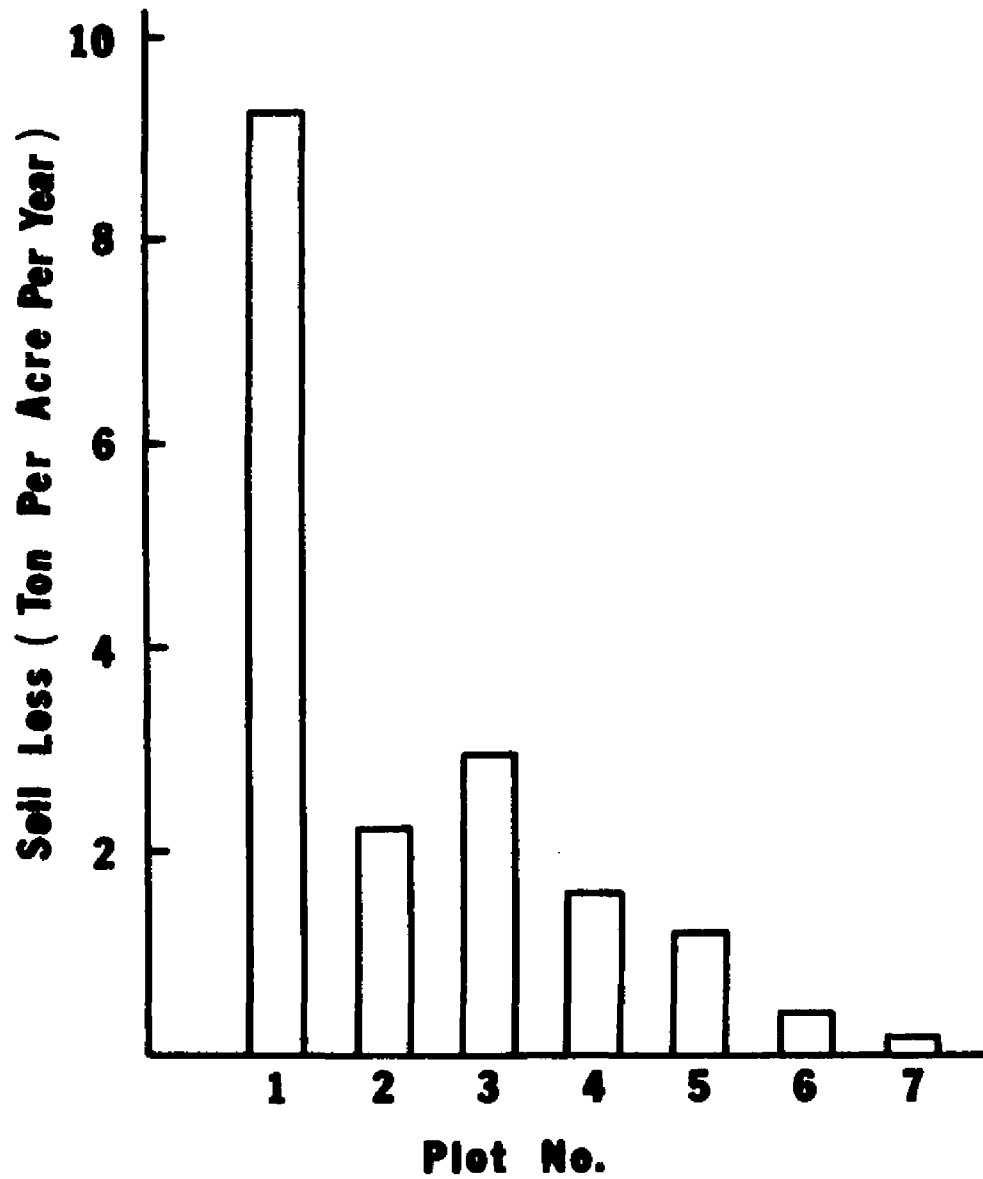


Figure 15. Average annual soil loss from different cropping and cultural systems (original rotation) for 19-year period at Tri-County Runoff Plots, Kalamazoo

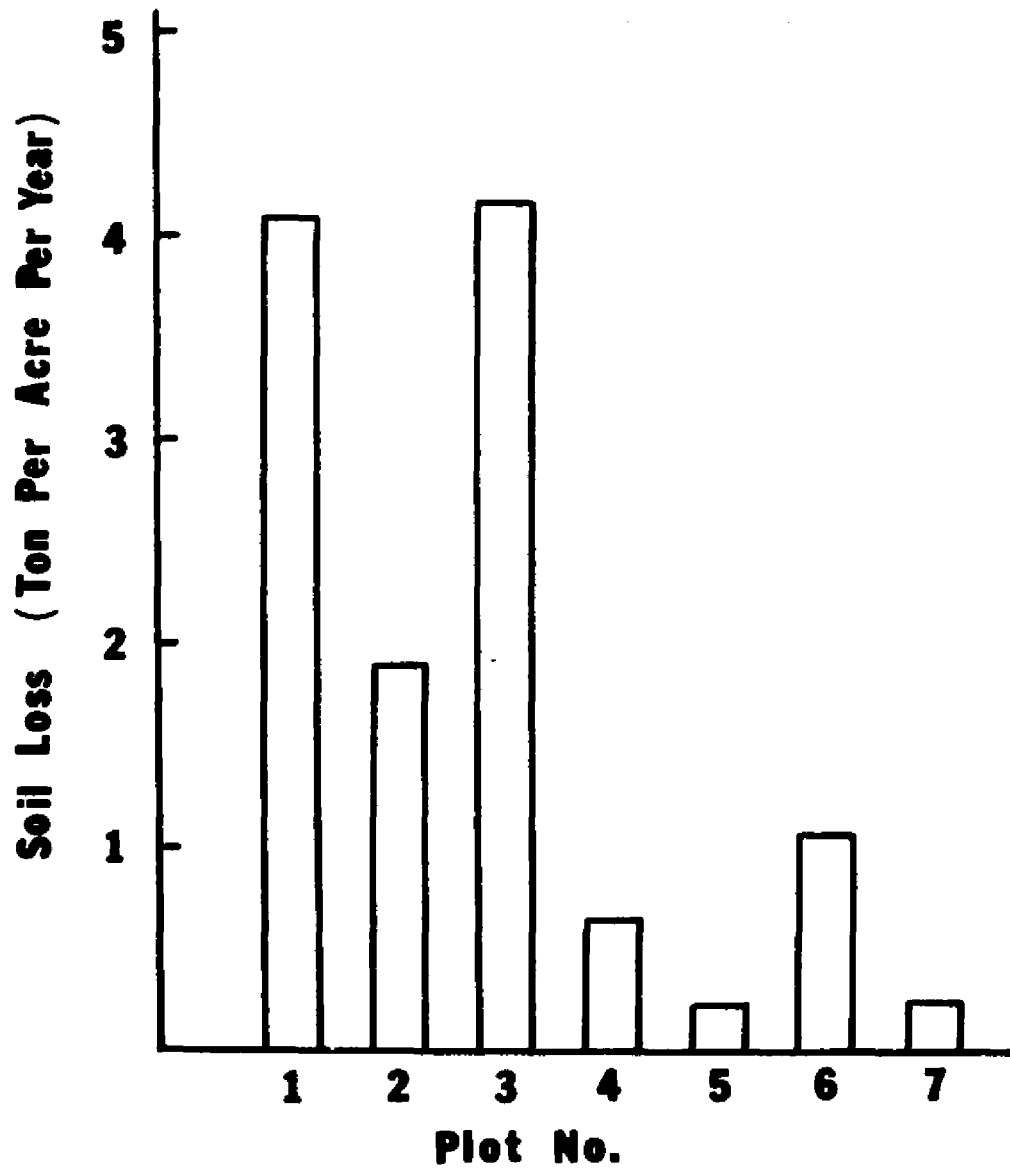


Figure 16. Average annual soil loss from different cropping and cultural systems (new rotation) for 3-year period at Tri-County Runoff Plots, Kalamazoo

Figure 11. The amounts of soil loss from the plots which received different cropping and cultural practices are highly significantly different. The amounts of soil loss from the same plot during this period varied widely from year to year.

The largest amount of soil loss was 9.22 tons per acre per year. This plot received up and down slope cultivation with corn grown annually. The plot with permanent meadow had the smallest amount of loss, 0.16 ton per acre per year. The average annual soil loss from plot 1 is significantly different from that of the other six plots. The reason for this can be explained as follows: soil under plot 1 has the longest period for exposure to rain, wind and sun as compared to the other six plots. The effective ground cover provided by corn at an early stage of growth is negligible and corn usually is planted early in the spring season. Soil under plot 1 has the longest period of soil exposure to erosive agents while the other six plots had winter grain, spring grain and meadow. These crops provide more effective cover for soil. The nature of small grain crops and meadow create better soil conditions to resist erosion than corn. Therefore, the amount of soil loss from plot 1 was the highest.

Plots with the same rotation system but different cultural practices resulted in no significant difference in soil loss. However, the soil losses are proportional to the difference in conservation practices factor. This can be observed from plots 2 and 3 which received the same rotation of corn-oats-wheat-meadow but plot 2 received contour cultivation and plot 3 received up and down slope tillage. The conservation factors for contour and up and down slope are 0.8 (for 16% slope) and 1.0 respectively. This effect also can be seen from plots 4 and 5 which have the same crop rotation of corn-oats-meadow-meadow but up and down slope tillage was performed on plot 4 and contour tillage on plot 5.

The rotation with the greatest number of years of meadow crop provided the amount of soil loss significantly different from the rotation with the smallest number of years of meadow crops. This effect can be seen from the amount of soil loss from plots 2 and 6. Average annual soil loss from plots 2 and 6 are 2.21 and 0.37 tons per acre per year, respectively. Both plots received contour tillage but corn-oats-wheat-meadow rotation for plot 2 and wheat-meadow-meadow-meadow for plot 6. These plots have the same value for conservation factor but difference in cropping management factor. The values of cropping management factor are 0.18 and

0.032 for plots 2 and 6, respectively. The soil losses of the two plots are approximately proportional to these values. The amount of soil loss from plot 2 is significantly different from plot 6 because soil under plot 6 has shorter period of exposure to erosive agents than plot 2 which contained corn and fewer number of years of meadow. Crop conditions to resist erosion of plot 6 is better than plot 2 which contains a smaller number of years of meadow crop.

The effect of cropping system on soil loss is greater than the cultural practices. This can be seen from the amount of soil loss from plots 3 and 4 which are significantly different. Both plots received up and down slope tillage but plot 3 had a corn-oats-wheat-meadow rotation and plot 4 had a corn-oats-meadow-meadow rotation. The amounts of soil loss from plots 3 and 4 are 2.91 and 1.55 tons per acre per year, respectively. Both plots have the same value for conservation factor but different in cropping management factor. The values of cropping management factor are 0.16 and 0.11 for plots 3 and 4, respectively. The soil losses are not proportional to these values. But this effect cannot be seen on contour tillage. Plots 2 and 5 received contour tillage but plot 2 contains corn-oats-wheat-meadow rotation and plot 5 contains corn-oats-meadow-meadow. Soil loss from plots 2 and 5 are 2.21 and

1.19 tons per acre per year respectively which are not significantly different. The soil losses are not proportional to these values.

A new rotation system was put into practice on these plots in 1973. The average annual soil loss from different cropping and cultural systems are shown in Table 21 and Figure 12. These data were statistically analyzed. The average soil loss from plots receiving different cropping and cultural systems is not significantly different but the amount of soil loss from each plot is highly significantly different from year to year. Because the new rotation started in 1973, the system is not completed; therefore, the average annual soil loss from each plot cannot be used to determine any effect of cropping or cultural system on the amount of soil loss.

Effect of cropping and cultural system on soil organic matter can be observed in Table 22 and Figure 17. These data were statistically analyzed. Soil organic matter content of surface horizon under different cropping and cultural systems is highly significantly different. The organic matter content is more closely related to the management of the plots from 1954 to 1973 than to that from 1974 to 1976. The highest amount of soil organic matter is found on plot 7 which received contour tillage and had permanent meadow.

Table 22. Organic matter content of surface horizons for Oshtemo series at Tri-county Runoff Plots (percentage)

Sample No.	Plot Number						
	I	II	III	IV	V	VI	VII
	R	R-W-M-M	R	R-W-M-M	R-O-W-M	R-O-W-M	M
	(up and down) Return	(across) Return	(up and down) Remove	(up and down) Return	(up and down) Remove	(across) Return	(across) Return
1	0.85	1.08	1.05	1.28	1.46	1.58	1.69
2	0.88	1.08	1.05	1.21	1.49	1.60	1.66
3	0.82	1.10	1.01	1.20	1.51	1.60	1.67
4	0.82	1.14	1.08	1.26	1.44	1.63	1.67
5	0.85	1.14	1.05	1.24	1.40	1.59	1.65
Average	0.84	1.11	1.05	1.24	1.46	1.60	1.67

L.S.D. (0.05); 0.04 percent

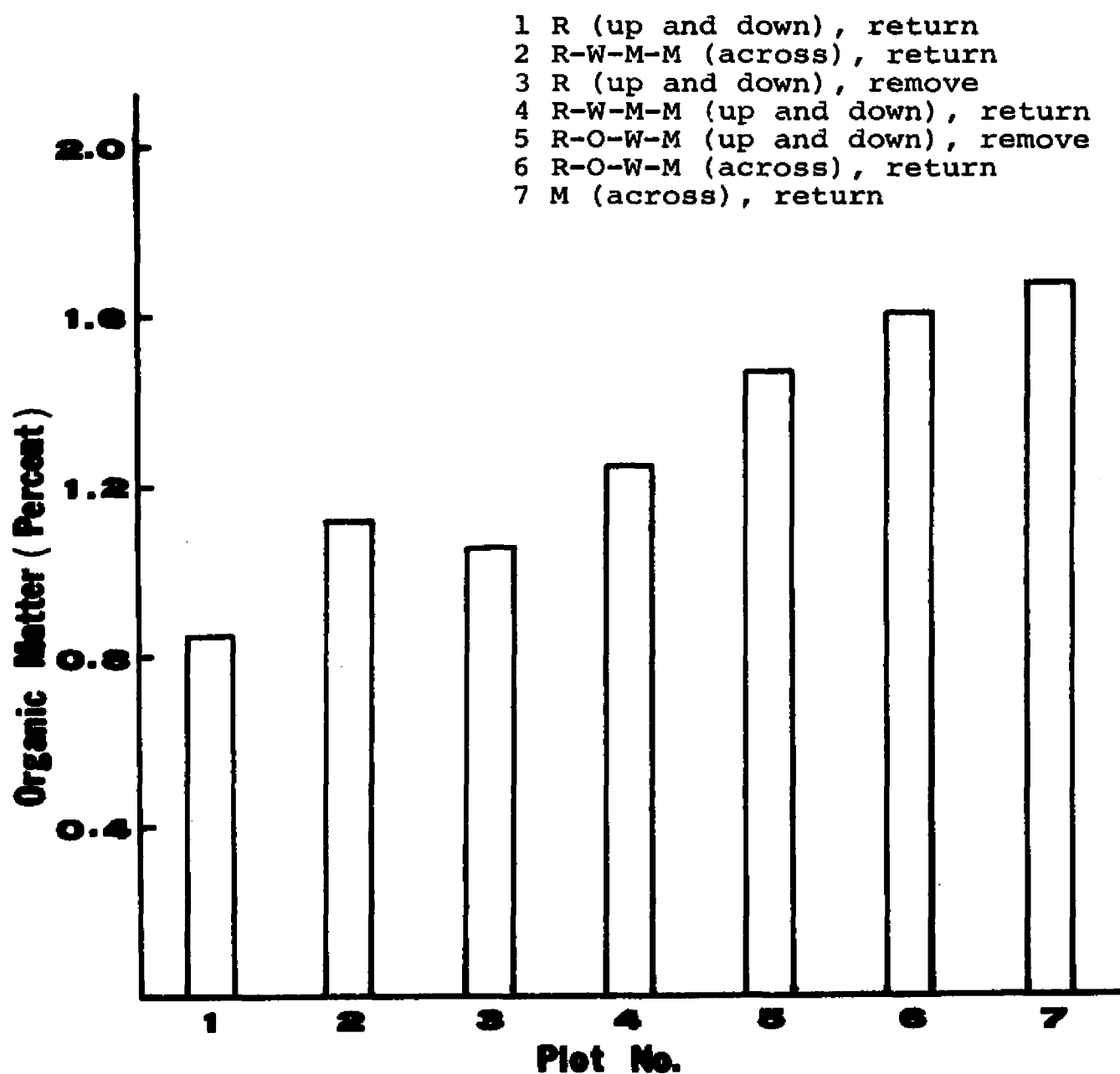


Figure 17. Organic matter content of surface soil as affected by different management systems at Tri-county Runoff plots

By using LSD at 0.05 level it is disclosed that the amounts of organic matter content in the surface horizon are significantly different among the seven plots. This is one property of soil to resist erosion of each plot which is different among seven plots. The data shown in Table 22 reveal that better soil management system increases soil organic matter.

Simplified Method of Communicating
Soil Loss Data to Young People

Pictorial graphs were selected to show the soil loss data from the erosion study plots. Soil loss data for 19-year period were taken from Tri-County Runoff Plots in Kalamazoo County. Two types of pictorial graphs are demonstrated as follows:

1. Use of a picture of a truck representing the amount of soil loss from each plot with different managements. The number of trucks for each plot can be seen in Figure 18.
2. Use of a picture of a bag representing the amount of soil loss from each plot. The number of bags for each plot informs the viewer how many tons of soil loss from that plot. This type of simplification can be seen in Figure 19.

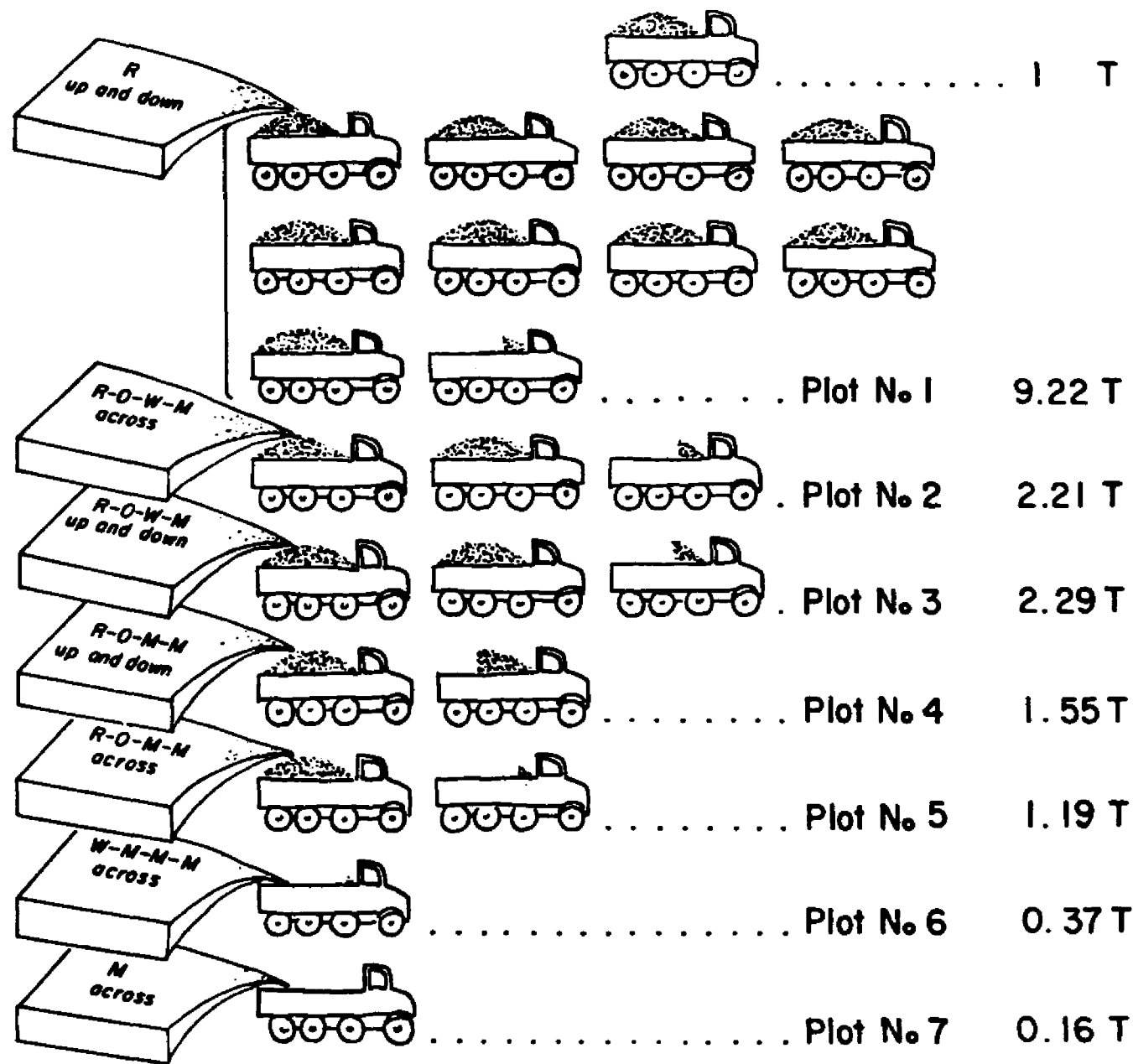


Figure 18. Average annual soil loss from different cropping and cultural systems for 19-year period at Tri-county runoff plots

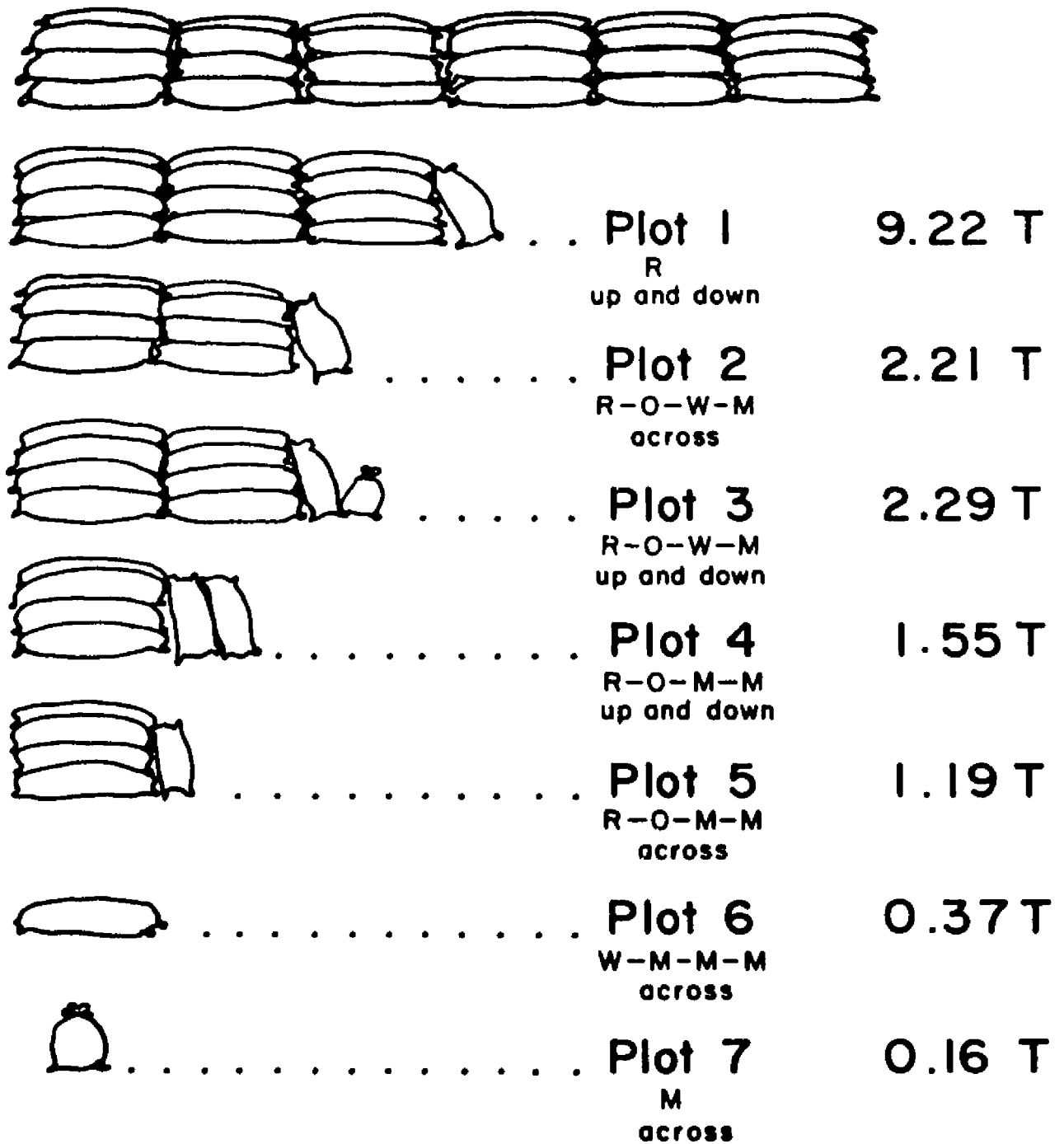


Figure 19. Average annual soil loss from different cropping and cultural systems for 19-year period at Tri-county runoff plots

The Explanation of Soil Erosion

The soil loss due to erosion from a field is related to rainfall, soil properties, slope, cropping system and conservation practices. The difference in soil loss from the plots is related to the cropping system and the conservation practice. The time and method of planting a crop is important. Corn is planted in wide rows in early spring. The corn plants provide very little protection for the soil against the spring rains. Meadow plants are close together and grow year round. These plants provide much protection for the soil against the spring rains. Oats is also planted in narrow rows but in early spring and provides some protection for the soil against the spring rains. Therefore, the number of years each crop is in a sequence will affect the amount of soil erosion. Corn grown every year (plot 1) had the most erosion and meadow every year (plot 7) had the least erosion. A crop sequence of corn-oats-wheat-meadow (plot 3) had less soil erosion than plot 1 but more than plot 7.

The direction the crop is planted, up and down the slope or across the slope, also affects soil erosion. When cultivating up and down slope the tillage equipment leaves small channels and wheel tracks for the runoff water to flow down the hill. When cultivating across the slope the equipment leaves small channels which act

as small dams for the water to retain some water and slow down the rate at which the runoff water flows down the hill. The faster the water flows the more soil it will erode. Plots 2 and 3 have the same crop sequence but plot 2 was cultivated across the slope and plot 3 was cultivated up and down the slope. Plot 2 had less soil erosion than plot 3. Plots 4 and 5 also had the same crop sequence. Plot 4 which was cultivated up and down slope had more soil erosion than plot 5 which was cultivated across the slope.

V. SUMMARY AND CONCLUSIONS

Soil erodibility of twenty-eight sites covering seven soil series and four soil management groups located in different counties in the lower peninsula of Michigan were studied using Wischmeier's nomograph. Soil erodibility for three soil series was determined from actual soil loss under field conditions. This procedure was accomplished by applying soil loss data to the Universal Soil-Loss Equation and then calculating the erodibility factor. Soil erodibility values obtained from Wischmeier's nomograph, U.S.D.A. Soil Conservation Service and from measuring actual soil loss under field conditions were compared. The effect of different cropping systems and cultural practices on soil loss on the three soil series at three different locations were studied. Average annual soil loss data obtained from three locations were statistically analyzed. From these studies, the following conclusions have been reached.

1. The soil erodibility factor value determined from soil properties by using the soil erodibility nomograph had a specific range for each soil series. The soil series belonging to soil management group 1.5a had the highest values and soil series belonging to soil management group 4a had the lowest values. The erodibility factor value increased as the percentage of silt increased and decreased as the percentage of sand increased.

2. Soil erodibility factors obtained from the erodibility nomograph, U.S.D.A. Soil Conservation Service and from measuring actual soil loss under field conditions were compared. It was found that the erodibility factor values obtained by measuring actual soil loss under field conditions were lower for all soils (three soil series and three soil management groups) than the other values. The erodibility factor values obtained from the U.S.D.A. Soil Conservation Service were the highest values for all soils. The K-values obtained from the nomograph were closer to the K values used by the U.S.D.A. Soil Conservation Service but were different from K values obtained by measuring actual soil loss under field conditions. The nomograph K value for soil series which belong to soil management group 4a was close to the K value obtained by measuring actual soil loss. The K values obtained from the nomograph were not constant

values for each soil series but varied with some soil properties within a limited range for each soil series.

3. The effects of cropping systems and cultural practices on soil loss were studied on three soil series and three locations. Average annual soil loss with different management systems were significantly different for one location at Burton Street Farm, Fenton, and highly significantly different for the other two locations in Kalamazoo and Muskegon counties. It is evident that cropping systems which increased soil loss were those that included a number of years of row crops. Continuous row crops contributed to the highest soil loss at every location and the smallest amount of loss was obtained from the plot with permanent meadow. The amount of soil loss from a plot decreased as the number of years of meadow increased. The amounts of soil loss from different cultivation systems were significantly different. With the same cropping system, contour tillage reduced soil erosion by half as compared with up and down slope cultivation. The conservation factors for contour tillage and up and down slope cultivation are 0.5 and 1.0 respectively and the values of cropping management factor were identical. The influence of cropping systems on soil erosion was greater than the influence of cultural practices (up and down slope tillage). Soil loss from the plot decreased as the

number of years of meadow in the cropping system increased. The cropping management factor for corn-oats-wheat-meadow and wheat-meadow-meadow-meadow rotations are 0.18 and 0.032 respectively.

4. The effects of different management systems on soil organic matter have been determined. It was found that the amount of organic matter under different cropping systems and cultural practices was highly significantly different. The lowest amount of soil organic matter was obtained from the plot with continuous row crop, and the highest amount of soil organic matter was obtained from the plot with permanent meadow. From these studies it was found that good cropping systems and cultural practices increased the organic matter content of soil.

5. Graphic techniques were chosen to simplify the soil loss data from erosion study plots for young people. Among the various graphic techniques, pictorial graphs were selected to present soil loss data. Two kinds of pictorial graphs were proposed for this purpose.

6. Future research for this subject should increase the number of soil samples and locations for each soil series. Since soil properties vary from location to location, the erodibility factor is affected. The established K factor by the soil erodibility

nomograph should be used within the specific area where the soil properties have been determined. It is necessary to establish an erosion study plot on different soil series and the plot should be operated for a number of years because the experience from this investigation reveals that the amount of soil loss from the same plot and location vary widely from year to year.

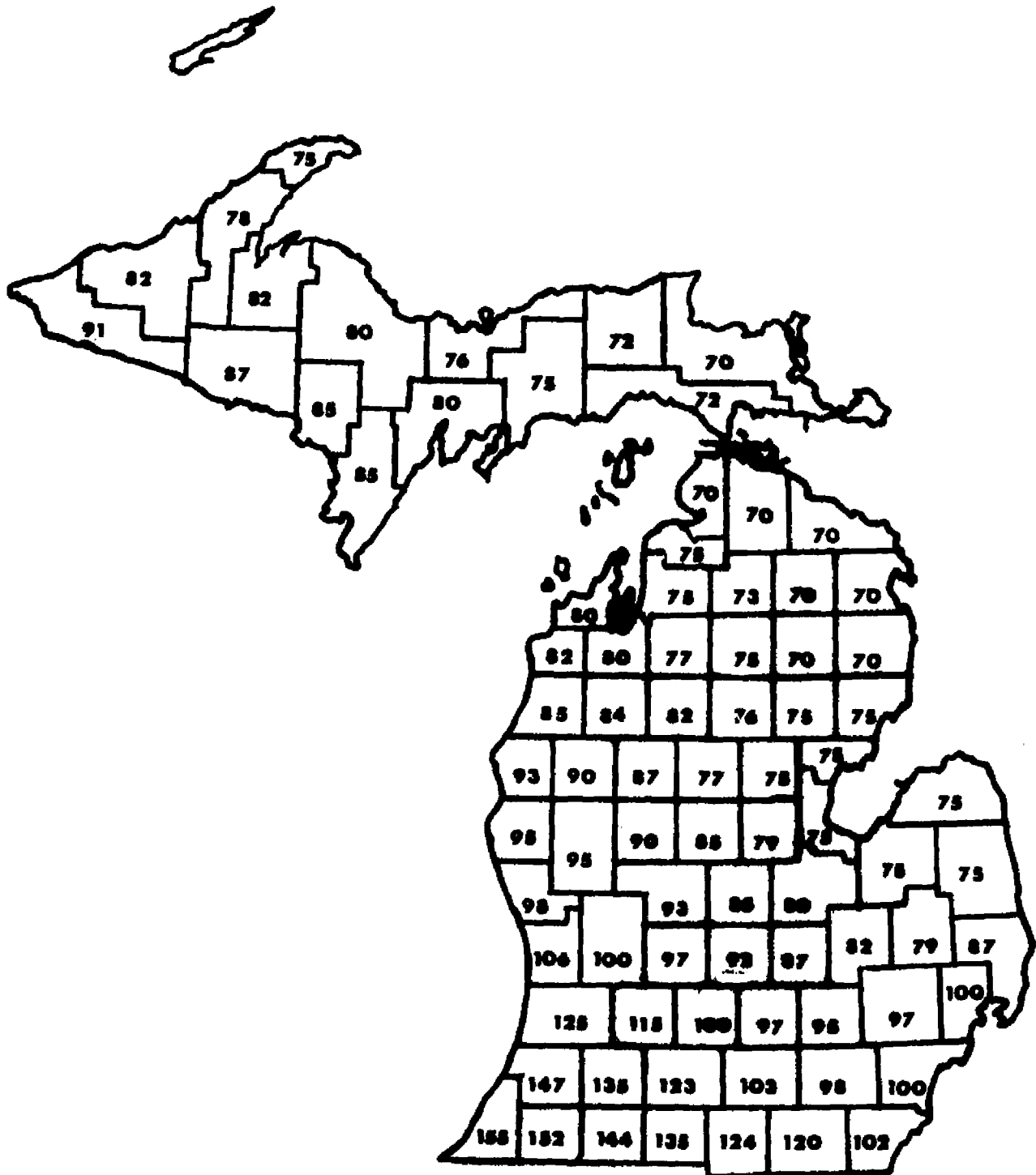
APPENDICES

APPENDIX A

RAINFALL FACTOR, R , FOR MICHIGAN COUNTIES

APPENDIX A

RAINFALL FACTOR, R, FOR MICHIGAN COUNTIES
(Tilmann et al., 1975)



APPENDIX B

SOIL ERODIBILITY "K" VALUES AND SOIL LOSS
TOLERANCE "T" VALUES

APPENDIX B

SOIL ERODIBILITY "K" VALUES AND SOIL LOSS

TOLERANCE "T" VALUES

Soil Series	"K"	"T"		Soil Series	"K"	"T"	
		Erosion				Erosion	
		1	2 3			1	2 3
Ahmeek	.37	4	4	Dighton	.43	3	2
Alcona	.32	3	2	Dowagiac	.32	3	2
Allouez	.24	4	3	Dresden	.32	3	2
Alpena	.24	2	1	Dryburg*	.24	4	3
Amasa	.32	3	2	Dryden	.32	3	2
Arkport	.32	3	2	Duel	.17	3	2
Baraga	.24	2	1	East Lake	.17	5	5
Barker	.37	3	2	Eastport	.17	5	5
Blount	.43	3	2	Elmdale*	.32	3	2
Blue Lake	.24	3	2	Elo	.37	3	2
Bohemian	.32	4	3	Emmet	.28	3	2
Boyer	.24	4	3	Fairport	.37	3	2
Brems*	.17	5	5	Fence*	.32	4	3
Bronson	.24	3	2	Fox	.32	3	2
Cadmus	.37	3	2	Froberg	.49	3	2
Casco	.24	3	2	Fulton	.49	3	2
Celina	.37	3	2	Gagetown	.37	4	3
Champion	.37	3	2	Gilchrist	.17	5	5
Chatham	.32	3	2	Gogebic	.32	3	2
Chelsea	.17	5	5	Goodman*	.37	4	3
Coloma	.17	5	5	Graycalm	.17	5	5
Coventry	.37	3	2	Grayling	.17	5	5

APPENDIX B (continued)

Soil Series	"K"	"T"		Soil Series	"K"	"T"	
		Erosion				Erosion	
		1 & 2	3			1 & 2	3
Crivitz	.17	5	5	Guelph	.37	3	2
Croswell	.20	5	5	Hillsdale	.32	4	3
Deer Park	.17	5	5	Huron	.49	3	2
Deerton	.17	3	2	Ionia	.32	3	2
Del Rey	.43	3	2	Iron River	.32	3	2
Johnswood	.37	3	2	Oakville	.17	5	5
Kalamazoo	.32	3	2	Ockley	.37	4	3
Kalkaska	.17	5	5	Ocqueoc*	.24	3	2
Karlin	.24	3	2	Omega	.17	5	5
Kendallville	.37	3	2	Omena*	.32	3	2
Kent	.49	3	2	Onaway	.32	3	2
Keweenaw	.24	3	2	Onota	.32	2	1
Kibbie	.37	4	3	Ontonagon	.43	3	2
Kiva	.24	2	1	Oshtemo	.24	3	2
Lapeer	.28	3	2	Ottawa	.17	5	5
Leelanau	.24	3	2	Ottokee	.17	5	5
Longrie	.32	3	2	Owosso	.28	4	3
Mancelona	.24	3	2	Padus*	.32	3	2
Manistee	.28	4	3	Parma	.32	2	1
Marlette	.37	3	2	Pence	.24	2	1
McBride	.32	3	2	Perrin	.24	3	2
Melita	.17	5	5	Plainfield	.17	5	5
Menominee	.28	4	3	Rimer	.24	4	3
Metea	.28	4	3	Roselms	.49	2	1
Miami	.37	3	2	Rousseau	.24	5	4
Michigamme	.32	2	1	Rubicon	.17	5	5
Montcalm	.24	3	2	Seward	.24	4	3
Morley	.43	3	2	Shelldrake	.17	5	5
Munising	.32	3	2	Sisson	.37	4	3

APPENDIX B (continued)

Soil Series	"K"	"T"		Soil Series	"K"	"T"	
		Erosion				Erosion	
		1	2 3			1	2 3
Nappanee	.49	3	2	Sparta	.17	5	5
Nester	.43	3	2	Spinks	.17	5	5
Newaygo	.32	3	2	Stambaugh	.37	3	2
Nunica*	.37	3	2	Steuben	.32	3	2
St. Clair	.49	3	2	Ubly	.28	4	3
St. Ignace	.32	2	1	Vilas	.17	5	5
Summerville	.32	2	1	Volinia	.32	3	2
Sunfield*	.32	3	2	Waiska	.24	2	1
Superior	.32	3	2	Wakefield*	.37	3	2
Trenary	.32	3	2	Wallace	.17	5	5
Tuscola	.37	4	3	Watton	.43	3	2
				Yalmer	.17	5	5

SOURCE: U.S. Soil Conservation Service, 1973

*Tentative Series

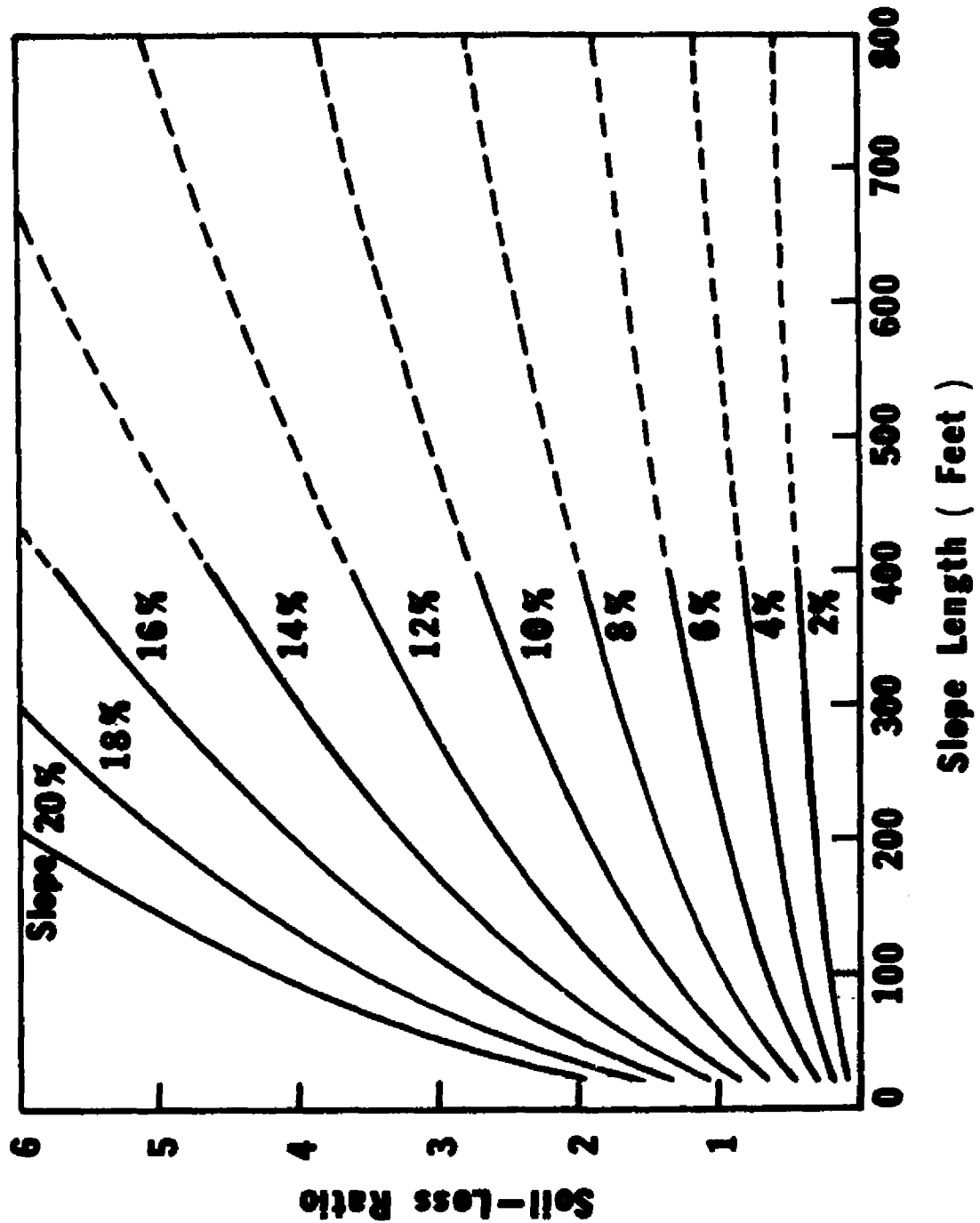
APPENDIX C

SLOPE-EFFECT CHART

APPENDIX C

SLOPE-EFFECT CHART

(Topographic factor, LS, Wischmeier
and Smith, 1965)



APPENDIX D

TABLE OF "C" VALUES

APPENDIX D

TABLE OF "C" VALUES

Explanatory Notes for the Table of "C" Values

1. Row crops with residues left includes corn and cultivated soybeans, where residues equal two or more tons per acre.
2. Corn for silage, potatoes, and truck crops or vegetables are considered row crops with residue removed.
3. Plow planting and wheel-track planting have the same value. Where one or more tillage operations are performed between plowing and planting row crops use columns for conventional tillage.
4. It is assumed that small grain residues are left on the land or, when removed, a good meadow seeding is present.
5. Following are the management factors associated with the cropping systems:
 - C_1 - Residues are left on the surface until planting time, row crops are wheel-track or plow planted and ground is spring plowed for oats.
 - C_2 - Same as C_1 except ground is disked in spring for oats.
 - C_3 - Residues are left, conventional tillage is used on row crops, ground is spring plowed for oats.
 - C_4 - Residues are left, conventional tillage is used on row crops and ground is fall plowed for oats.
 - C_5 - Residues are removed, conventional tillage is used for row crops and ground is spring plowed for oats.
 - C_6 - Residues are removed, row crops are wheel-track or plow planted and ground is spring plowed for oats.
6. "C" values for other rotations or management systems may be interpolated by making comparisons with the ones shown in Appendix D-5.

APPENDIX D (continued)

"C" VALUES

Crop Management Factor Values for Lower Michigan

Ratio of Soil Loss from Cropping Systems to
Loss from Continuous Fallow

Management and Yield Levels

Cropping System	C ₁			C ₂		
Residue = Rd						
Row Crop = R						
Spring Grain = O	Rd. Left			Rd. Left		
Winter Grain = W	R - W-T Pltd.	5-20		R - W-T Pltd.	5-20	
Cover Crop = x	O - Plowed	4-10		O - Disked	4-15	
Corn Yield = Bu.	40-59	60-74	75+	40-59	60-74	75+
Hay Yield = T.	1-2	2-3	3+	1-2	2-3	3+
Cont. Corn	.39	.32	.26	.39	.32	.26
R-R-R-O _x	.29	.24	.20	.28	.23	.19
R-R-O _x	.26	.22	.19	.24	.20	.17
R _x -R _x	.25	.20	.18	.25	.20	.18
R _x -R _x -R-O _x	.23	.19	.17	.23	.18	.16
R _x -R-O _x	.22	.19	.17	.22	.17	.14
R-O _x	.19	.17	.15	.18	.14	.13
R-R-R-O-M	.20	.16	.13	.19	.15	.12
R _x -R _x -R-O-M	.15	.13	.11	.15	.12	.10
R-O-W-M	.13	.12	.11	.12	.10	.091
R-R-O-M	.15	.12	.10	.14	.10	.085
R-O-M-W	.11	.10	.095	.11	.093	.082
R _x -R-O-M	.13	.11	.09	.13	.09	.077
R-R-O-M-M	.12	.094	.079	.11	.084	.069
R-O-W-M-M-M	.088	.081	.071	.081	.07	.061
R-R-O-M-M-M	.10	.08	.067	.097	.071	.058
R-O-M-M-M-W _x	.078	.07	.064	.077	.063	.056
R-O-M	.09	.078	.06	.077	.057	.04
W-O-M-M	.058	.057	.048	--	--	--

APPENDIX D (continued)

Cropping System	C ₁			C ₂		
Residue = Rd						
Row Crop = R						
Spring Grain = O	Rd. Left			Rd. Left		
Winter Grain = W	R - W-T Pltd. 5-20			R - W-T Pltd. 5-20		
Cover Crop = x	O - Plowed 4-10			O - Disked 4-15		
Corn Yield = Bu.	40-59	60-74	75+	40-59	60-74	75+
Hay Yield = T.	1-2	2-3	3+	1-2	2-3	3+
R-O-M-M	.07	.06	.047	.06	.044	.032
R-O-M-M-M	.057	.049	.038	.05	.036	.026
W-M	.045	.045	.038	--	--	--
W-M-M	.032	.031	.027	--	--	--
O-M-M	.025	.024	.021	--	--	--
Cropping System	C ₃			C ₄		
	Rd. Left			Rd. Left		
	R - W-T Pltd. 5-20			R - Plowed 5-5		
	O - Plowed 4-10			O - Plowed 10-20		
Cont. Corn	.50	.44	.39	.50	.44	.39
R-R-R-O _x	.37	.33	.30	.38	.34	.31
R-R-O _x	.33	.29	.26	.34	.31	.28
R _x -R _x	.38	.34	.31	.38	.34	.31
R _x -R _x -R-O _x	.32	.29	.26	.33	.30	.27
R _x -R-O _x	.30	.27	.24	.32	.29	.25
R-O _x	.25	.22	.20	.27	.25	.22
R-R-R-O-M	.25	.21	.19	.26	.23	.20
R _x -R _x -R-O-M	.22	.19	.17	.24	.21	.18
R-O-W-M	.15	.14	.12	.16	.14	.13
R-R-O-M	.20	.16	.14	.21	.18	.15
R-O-M-W	.14	.13	.12	.16	.14	.13
R _x -R-O-M	.18	.15	.13	.20	.17	.14
R-R-O-M-M	.16	.13	.11	.17	.15	.12
R-O-W-M-M-M	.10	.094	.082	.11	.098	.086
R-R-O-M-M-M	.13	.11	.095	.14	.12	.10

APPENDIX D (continued)

Cropping System	C ₃			C ₄		
	Rd. Left			Rd. Left		
	R - W-T Pltd.	5-20		R - Plowed	5-5	
	O - Plowed	4-10		O - Plowed	10-20	
R-O-M-M-M-W _x	.10	.088	.08	.11	.098	.086
R-O-M	.12	.10	.083	.14	.12	.097
W-O-M-M	.058	.057	.048	.076	.075	.058
R-O-M-M	.094	.079	.063	.10	.092	.074
R-O-M-M-M	.076	.064	.051	.084	.075	.06
W-M	.045	.045	.038	.045	.045	.038
W-M-M	.032	.031	.027	.032	.031	.027
O-M-M	.025	.024	.021	.035	.033	.03
Cropping System	C ₅			C ₆		
	Rd. Removed			Rd. Removed		
	R - Plowed	5-5		R - W-T Pltd.	5-20	
	O - Plowed	4-10		O - Plowed	4-10	
Residue = Rd						
Row Crop = R						
Spring Grain = O						
Winter Grain = W						
Cover Crop = x						
Corn Yield = Bu.	40-59	60-74	75+	40-59	60-74	75+
Hay Yield = T.	1-2	2-3	3+	1-2	2-3	3+
Cont. Corn	.58	.56	.52	.53	.50	.46
R-R-R-O _x	.43	.41	.37	.38	.35	.32
R-R-O _x	.38	.35	.32	.33	.30	.27
R _x -R _x	--	.46	.44	--	.33	.31
R _x -R _x -R-O _x	.38	.36	.33	.30	.27	.25
R _x -R-O _x	.34	.32	.29	.28	.25	.22
R-O _x	.28	.25	.22	.23	.20	.18
R-R-R-O-M	.30	.28	.24	.25	.21	.20
R _x -R _x -R-O-M	.27	.25	.22	.22	.19	.16
R-O-W-M	.18	.17	.15	.16	.15	.13
R-R-O-M	.24	.21	.18	.19	.16	.15
R-O-M-W	.16	.15	.13	.14	.12	.11
R _x -R-O-M	.21	.19	.17	.18	.15	.12

APPENDIX D (continued)

Cropping System	C ₅			C ₆		
	Rd. Removed			Rd. Removed		
	R - Plowed	5-5		R - W-T Pltd.	5-20	
	O - Plowed	4-10		O - Plowed	4-10	
R-R-O-M-M	.19	.17	.15	.16	.13	.12
R-O-W-M-M-M	.12	.11	.10	.11	.10	.088
R-R-O-M-M-M	.16	.14	.12	.13	.11	.10
R-O-M-M-M-W _x	.11	.10	.088	.092	.083	.072
R-O-M	.14	.12	.10	.11	.095	.079
W-O-M-M	.094	.091	.084	--	--	--
R-O-M-M	.11	.092	.076	.081	.072	.06
R-O-M-M-M	.087	.074	.062	.066	.06	.05
W-M	--	--	--	--	--	--
W-M-M	--	--	--	--	--	--
O-M-M	--	--	--	--	--	--

SOURCE: U.S. Soil Conservation Service, 1973

APPENDIX D (continued)

"C" Values for Conservation Tillage, Soil Conservation Service, Michigan, Lower Peninsula
(U.S. Soil Conservation Service, 1973)

	Till plant, chisel plow & rotary strip tillage ^a					Zero Tillage-NoTill or Slot planting ^b				
	pounds corn residue on surface/acre ^c					pounds corn residue on surface/acre ^c				
	1000- 2000	2000- 3000	3000- 4000	4000- 6000	6000+	1000- 2000	2000- 3000	3000- 4000	4000- 6000	6000+
1. Cont. corn ^d	.355	.244	.189	.131	.080	.284	.193	.131	.070	.030
2. Cont. corn ^d RdR, Cover Crop RdL	.343	.239	.219	.206		.253	.196	.180	.163	
3. RRROx ^d	.185	.136	.111	.085	.062	.150	.097	.080	.052	.034
4. RROx ^d	.125	.097	.083	.068	.056	.103	.079	.062	.045	.036
5. RRROM ^d	.149	.109	.086	.069	.051	.122	.088	.065	.043	.028
6. RRROMM ^d	.125	.092	.072	.058	.043	.102	.074	.055	.036	.024
7. RROM ^d	.094	.074	.063	.052	.043	.079	.060	.047	.035	.028
8. RROMM ^d	.076	.060	.051	.042	.035	.064	.048	.038	.029	.023
9. RROMMM ^d	.064	.050	.043	.036	.030	.054	.041	.033	.025	.020
10. ROM		.042					.036			
11. ROMM		.032					.028			
12. ROMMM		.027					.023			
13. ROMMMM		.023					.020			
14. OMMMM										

^aIncludes tillage systems which leave residues on 66% or more of the soil surface after planting.

^bIncludes tillage systems which leave residues on 90% or more of the soil surface after planting.

^cOne pound of residue from small grain, hay crops, and soybeans is equivalent to two pounds of corn residue.

^dWhen soybeans are grown; Continuously - Increase "C" factor by 20-25%; one-half of R crop - Increase "C" factor by 15%. One-third of R crop - Increase "C" factor by 10%. (When computing corn residue, assume that there will be one pound of stalks with each pound of grain produced. Corn (shelled) equals 56 pounds per bushel. Therefore, 110 bushels of corn will yield 6160 pounds of residue.

APPENDIX D (continued)

"C" Values for Representative Cropping Systems
(Mokma, undated)

Cropping System ^b Yields of:	Management System and Yield Levels ^a								
	Conv. till no residues			Conv. till. + resi- dues or min. till no residues			Min. till + Residues		
	40-59 1-2	60-74 2-3	75+ 3+	40-59 1-2	60-74 2-3	75+ 3+	40-59 1-2	60-74 2-3	75+ 3+
corn (bu/A.)----									
hay (t/A.)-----									
R(cont. row crop)	.58	.56	.52	.51	.47	.42	.39	.32	.26
RRRO _x	.43	.41	.37	.37	.34	.31	.29	.24	.20
RRO _x	.38	.35	.32	.33	.29	.26	.26	.22	.19
R _x R _x	--	.46	.44	.38	.34	.31	.25	.20	.18
R _x R _x RO _x	.38	.36	.33	.31	.28	.26	.23	.19	.17
R _x RO _x	.34	.32	.29	.26	.23	.23	.23	.19	.17
RRROM	.30	.28	.24	.25	.21	.19	.20	.16	.13
RO _x	.28	.25	.22	.24	.21	.19	.19	.17	.15
R _x R _x ROM	.27	.25	.22	.22	.19	.17	.15	.13	.11
RROM	.24	.21	.18	.20	.16	.14	.15	.12	.10
R _x ROM	.21	.19	.17	.18	.15	.13	.13	.11	.09
ROWM	.18	.17	.15	.15	.14	.12	.13	.12	.11
ROMW	.16	.15	.13	.14	.13	.12	.11	.10	.095
RROMM	.19	.17	.15	.16	.13	.11	.12	.094	.079
RROMMM	.16	.14	.12	.13	.11	.097	.10	.08	.067
ROM	.14	.12	.10	.12	.097	.081	.09	.078	.06
ROWMMM	.12	.11	.10	.105	.097	.085	.088	.081	.071
ROMMMW _x	.11	.10	.088	.097	.085	.076	.078	.07	.064
ROMM	.11	.092	.076	.087	.075	.063	.07	.06	.047
WOMM	.094	.091	.084	.058	.057	.048	.058	.057	.048
ROMMM	.087	.074	.062	.071	.065	.051	.057	.049	.038
WM	--	--	--	.045	.045	.038	.045	.045	.038
WMM	--	--	--	.032	.031	.027	.032	.031	.027
OMM	--	--	--	.025	.024	.021	.025	.024	.021
M-Alf.								.02	
M-Red Cl.								.015	
M-Alf. Brome							.006		.004

^aConv. till = conventional tillage; min. till. = minimum tillage; no residues = removal of crop residues or crops which produce less than 2 tons per acre of residues (corn for silage, potatoes, field beans and vegetable crops); + residues = leaving crop residues on land surface.

^bEach cropping system is abbreviated by substituting a letter for each crop. R = row crop; O = spring small grain; W = winter small grain; M = meadow or hay crop; x = cover crop.

APPENDIX E

CONSERVATION PRACTICE FACTOR VALUES

APPENDIX E

CONSERVATION PRACTICE FACTOR VALUES

Percentage Slope	P_c	P_{sc}	P_{tc}
	Contouring	Strip Cropping ^a	Terracing and Contouring
Parallel to Field Boundary	0.8 ^b	---	---
1.1- 2	0.6	0.30	---
2.1- 4	0.5	0.25	0.10
4.1- 7	0.5	0.25	0.10
7.1-12	0.6	0.30	0.12
12.1-18	0.8	0.40	0.16
18.1+	0.9	0.45	---

SOURCE: Schwab et al., 1966, page 181

^aA system using 4-year rotation of corn, small grain, meadow, meadow

^bFor slope up to 12% only

APPENDIX F

PERMEABILITY CLASSES

APPENDIX F

PERMEABILITY CLASSES

		Possible Rates in Inches per Hour
Slow		
1	Very slow	less than 0.05
2	Slow	0.05 to 0.20
Moderate		
3	Moderate slow	0.20 to 0.80
4	Moderate	0.80 to 2.50
5	Moderate rapid	2.50 to 5.00
Rapid		
6	Rapid	5.00 to 10.00
7	Very rapid	over 10.00

SOURCE: Soil Survey Staff, 1951

APPENDIX G

TYPES AND CLASSES OF SOIL STRUCTURE

APPENDIX G

TYPES AND CLASSES OF SOIL STRUCTURE

CLASS	TYPE (Shape and Arrangement of Peds)		
	Platelike with one dimension (the vertical) limited and greatly less than the other two; arranged around a horizontal plane; faces mostly horizontal.	Prismlike with two dimensions (the horizontal) limited and considerably less than the vertical; arranged around a vertical line; vertical faces well defined; verticles angular.	
		Without rounded caps.	With rounded caps.
	Platy	Prismatic	Columnar
Very fine or very thin.	Very thin platy; <1 mm.	Very fine prismatic; < 10 mm.	Very fine columnar; <10 mm.
Fine or thin___	Thin platy; 1 to 2 mm.	Fine prismatic; 10 to 20 mm.	Fine columnar; 10 to 20 mm.
Medium_____	Medium platy; 2 to 5 mm.	Medium prismatic; 20 to 50 mm.	Medium columnar; 20 to 50 mm.
Coarse or thick	Thick platy; 5 to 10 mm.	Coarse prismatic; 10 to 100 mm.	Coarse columnar; 50 to 100 mm.
Very coarse or very thick	Very thick platy; > 10 mm.	Very coarse prismatic; > 100 mm.	Very coarse columnar; > 100 mm.

APPENDIX G (continued)

TYPE (Shape and Arrangement of Peds)			
Blocklike; polyhedronlike, or spheroidal, with three dimensions of the same order of magnitude, arranged around a point.			
Blocklike; blocks or polyhedrons having plane or curved surfaces that are casts of the molds formed by the faces of the surrounding peds.		Spheroids or polyhedrons having plane or curved surfaces which have slight or no accommodation to the faces of surrounding peds.	
Faces flattened; most vertices sharply angular.	Mixed rounded and flattened faces with many rounded vertices.	Relatively non-porous peds.	Porous peds.
(Angular) Blocky ^a	Subangular blocky ^b	Granular	Crumb
Very fine angular blocky; 5 mm.	Very fine subangular blocky; 5 mm.	Very fine granular; 1 mm.	Very fine crumb; 1 mm.
Fine angular blocky; 5 to 10 mm.	Fine subangular blocky; 5 to 10 mm.	Fine granular; 1 to 2 mm.	Fine crumb; 1 to 2 mm.
Medium angular blocky; 10 to 20 mm.	Medium subangular blocky; 10 to 20 mm.	Medium granular; 2 to 5 mm.	Medium crumb; 2 to 5 mm.
Coarse angular blocky; 20 to 50 mm.	Coarse subangular blocky; 20 to 50 mm.	Coarse granular 5 to 10 mm.	
Very coarse angular blocky; 50 mm.	Very coarse subangular blocky; 50 mm.	Very coarse granular; 10 mm.	

SOURCE: Soil Survey Staff, 1951

^a(1) Sometimes called nut. (2) The word "angular" in the name can ordinarily be omitted.

^bSometimes called nuciform, nut, or subangular nut. Since the size connotation of these terms is a source of great confusion to many, they are not recommended.

APPENDIX H

**MONTHLY PRECIPITATION FOR 23-YEAR PERIOD AT
TRI-COUNTY RUNOFF PLOTS, KALAMAZOO**

APPENDIX H

MONTHLY PRECIPITATION FOR 23-YEAR PERIOD AT TRI-COUNTY RUNOFF PLOTS, KALAMAZOO

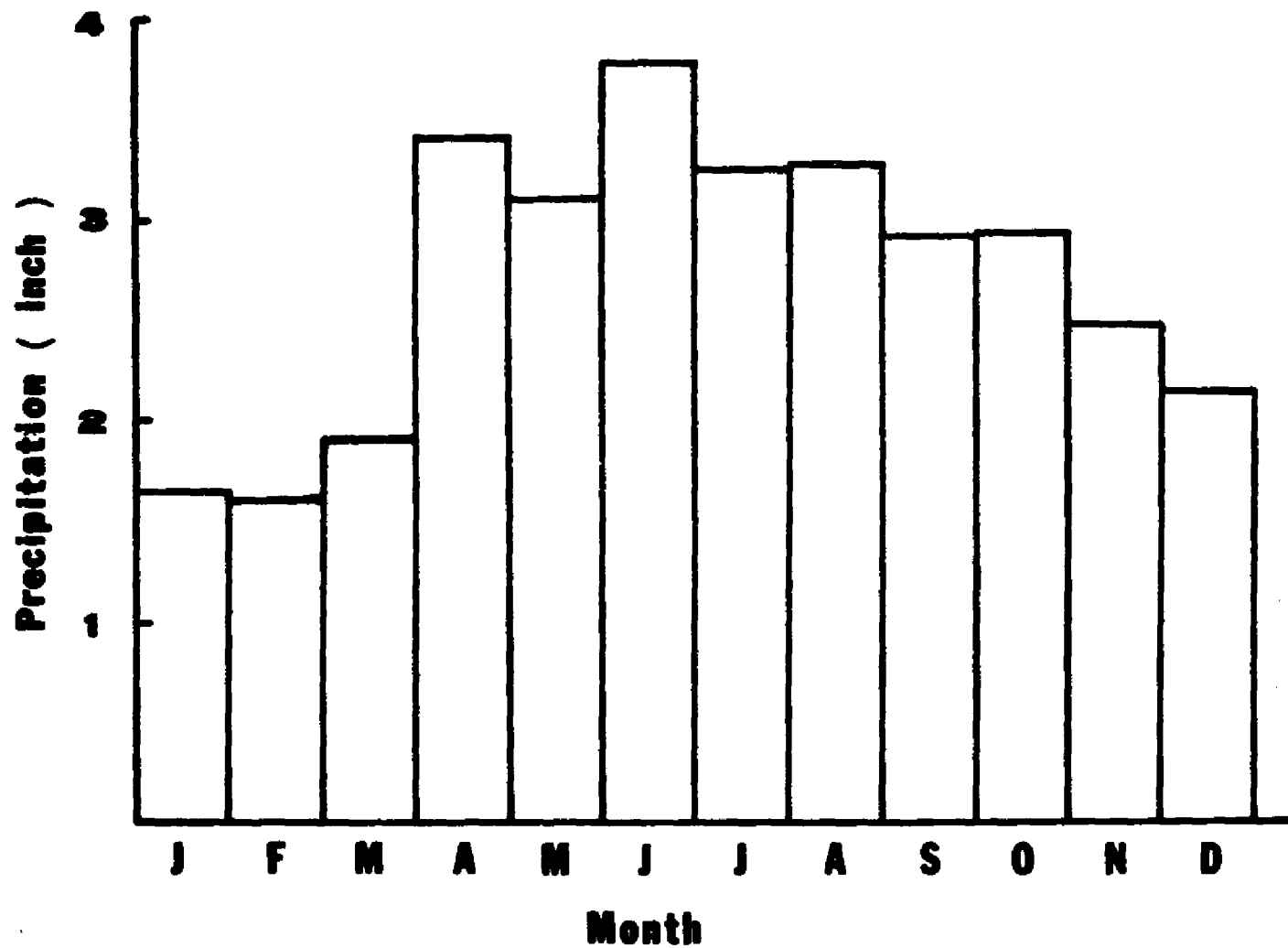
Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1954	1.66	2.66	2.65	3.38	0.94	8.34	2.70	3.31	2.98	8.67	2.51	1.73
1955	1.37	1.65	1.72	2.81	1.91	4.75	3.48	3.28	1.53	5.24	2.70	0.44
1956	1.10	1.63	1.90	4.63	3.75	3.67	2.43	1.87	0.62	0.24	1.13	0.81
1957	2.95	1.23	3.39	5.38	4.29	3.01	4.62	3.05	1.82	4.42	2.85	3.26
1958	0.83	2.98	0.56	2.03	1.39	6.26	3.28	4.29	2.44	1.75	2.40	0.43
1959	2.31	2.08	1.49	2.52	2.53	4.38	3.88	4.39	3.10	4.62	1.86	1.68
1960	2.94	1.98	0.56	2.88	5.12	4.78	3.19	2.57	2.39	1.05	1.83	0.96
1961	0.28	0.51	1.88	3.73	1.73	3.27	2.50	5.15	6.24	2.54	1.37	0.74
1962	2.35	0.43	0.77	1.77	3.19	3.79	2.79	1.26	3.54	2.70	0.39	1.51
1963	0.82	0.37	1.37	2.28	4.25	1.54	4.05	1.81	1.02	0.84	1.20	0.48
1964	0.50	0.32	2.01	3.69	2.44	2.13	2.61	4.93	4.72	1.19	2.74	1.43
1965	2.05	1.35	1.94	1.89	1.97	3.21	2.21	5.21	5.18	2.26	2.04	4.53
1966	0.93	1.57	3.25	4.48	3.53	2.22	2.16	5.13	1.73	1.03	6.56	3.92
1967	2.73	1.61	1.12	4.73	2.34	6.03	2.88	1.90	3.08	5.13	3.08	5.01
1968	1.66	2.65	0.73	2.95	3.25	6.59	5.37	3.44	4.17	3.49	4.49	3.51
1969	1.74	0.28	1.83	4.95	2.79	5.60	4.49	1.56	0.43	5.56	3.12	0.72
1970	0.82	0.75	2.37	3.49	4.09	3.62	5.63	1.63	3.24	4.40	3.05	1.55
1971	1.09	2.92	1.63	1.14	2.33	1.63	5.64	1.86	4.53	3.51	3.10	4.60
1972	1.58	1.09	2.34	3.39	3.79	2.70	4.94	6.27	6.15	3.10	2.31	4.63
1973	1.33	1.48	3.61	3.71	6.06	3.63	3.77	1.65	4.57	3.04	3.68	2.70
1974	2.36	3.10	3.91	4.95	3.44	3.63	1.36	2.92	3.43	1.55	2.92	1.26
1975	3.38	4.2	2.18	6.48	6.02	2.74	0.13	10.43	1.8	0.99	3.06	4.42
1976	2.76	1.97	2.47	4.60	3.25	2.86	3.93	0.45	2.18	2.72	1.38	1.35
Total	39.54	38.75	45.68	81.86	74.40	90.38	77.98	78.36	69.89	70.04	59.77	51.67
Average	1.65	1.61	1.90	3.41	3.10	3.77	3.25	3.26	2.91	2.92	2.49	2.15

APPENDIX I

MEAN MONTHLY PRECIPITATION FOR 23-YEAR PERIOD
AT TRI-COUNTY RUNOFF PLOT, KALAMAZOO

APPENDIX I

MEAN MONTHLY PRECIPITATION FOR 23-YEAR PERIOD
AT TRI-COUNTY RUNOFF PLOT, KALAMAZOO



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