Soil Erosion by Water: An Unsolved Problem
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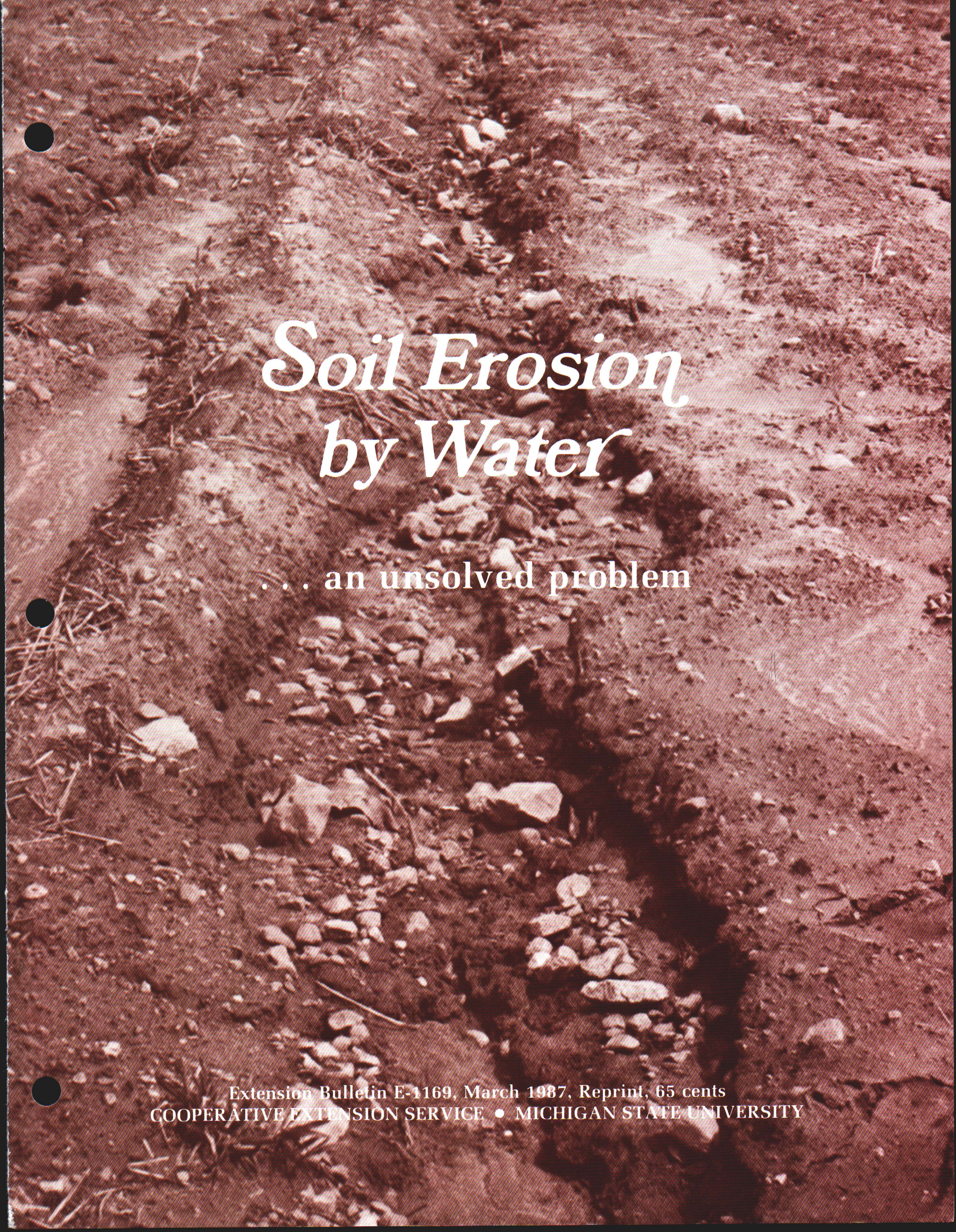

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Soil Erosion by Water

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Soil erosion in Michigan is an unsolved and poorly understood problem. This situation exists because erosion is not as severe here as in other states, and because soil losses are often too small to be seen or measured.

The water erosion problem is increasing because great changes in land use are occurring. Larger farms and fields, fewer fences and field boundaries, more late summer, fall, and early winter plowing, larger and heavier farm implements, and increased use of effective herbicides result in more erosion than in the past.

Research on watersheds at East Lansing shows that frequently soil losses due to water runoff are too small to be measured (2,3, see References, page 8). However, severe erosion occurred when precipitation totals and rainfall intensities were above average. Cook and Erickson (2) measured soil losses on a Hillsdale loam with a 4 to 6% slope after moldboard plowing, disking twice, harrowing twice, and then planting corn across the slope. The soil loss for a 4-year period, including 1 year when no erosion occurred, totaled 39,433 lb. or 19.75 tons per acre. During the same period, corn grain yields totaled 379 bu. per acre (94.8 bu. per acre per year). This was equivalent to 20,471 lb., which is 18,962 lb. less than the weight of the eroded soil. Such data serve in part as a basis for believing that while the erosion problem in Michigan may not be as great as elsewhere, it is significant and action should be taken to reduce the magnitude of the problem.

A potential erosion-related problem is that of federal legislation on nonpoint pollution (Section 208 of the 1972 Amendments to the Federal Water Pollution Control Act of 1966). Environmentalists were asking questions. They wanted legislation to prevent nonpoint pollution such as soil erosion because they believed that land users in general and crop and livestock producers in particular were responsible for a degradation in the quality of the nation's water.

Because so little data are available to refute (or validate) this contention, it is essential that all producers become concerned about erosion associated with specific soil management practices. When data become available, hopefully Michigan farmers can say with pride that their contributions to nonpoint pollution are small and that the need for erosion legislation as related to crop production is minimal or even nonexistent. Currently, Michigan's Soil Erosion and Sedimentation Control Act of 1972 as amended by Act 197 in 1974 does not apply to tillage for crop production.

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Soil Erosion Problems

Michigan's citizens are all affected by soil erosion. Obviously, farmers are hurt when erosion oc-

Figure 1. Variable stands of corn reflect severely eroded areas, which results in wasted seed and fertilizer and in reduced yields. Furthermore, with such stands, the soil in the eroded area remains unprotected for the entire season.

curs, but so are urbanites and suburbanites. Who pays to keep the Saginaw River deep enough for oceangoing ships, to clean a county ditch, to remove sediment after a flood, to repair a washed-out road, to replant a crop after it was smothered by silt and clay, or for a crop that failed due to soil crusts? If all rainwater and snowmelt entered the soil or moved across the surface at a slow rate, erosion would be minimal.

There are many problems associated with soil erosion. To illustrate the extent and kinds of damage, here are eight common problems.

Loss of Top Soil

The topsoil contains most of the available, essential plant food elements and organic matter. Thus, when topsoil moves to another site, the remaining soil has lost its natural functions of plant anchorage and storehouse of air, water, and plant nutrients. An estimated 40 million tons of soil are lost from Michigan's 11 million acres of cropland each year (4). This is more weight and volume than the 152.8 million bu. of corn produced in 1975, the record high (5). On an acre basis, the soil loss was about 3.6 tons and corn production was 80 bu. or 2.4 tons.

Soil Structure Damage

Splash erosion (see section on "Kinds of Water Erosion") breaks down the natural structure of soil. When soil dries, crusts form and plants have difficulty emerging. Crusts reduce both rate and quantity of air moving into the soil. Also, water infiltration rates are lowered to such an extent that flooding and erosion sometimes occur even with modest rains (7). In the breakdown of aggregates, small soil particles are trapped in large pores, reducing the pore size and the rate of water movement through the soil.

When silt-loaded water moves across the soil's surface, some moves down into the plow layer and even into the subsoil. The silt is trapped in the pores, thus reducing both total soil porosity and non-capillary porosity (air porosity). This in turn reduces water infiltration rates and permeability, causing more runoff and increasing erosion potential.

Reduced Yield Potential

Eroded soil represents an undesirable media for seed germination and root growth (Figure 1), a condition demanding higher fertilizer rates. This is shown in a recent summary of soil test levels in the profiles of soil used for corn production in Michigan (9). Available phosphorus in the plow layer of naturally well-drained loam soil averaged 74 lb. per acre. Levels in the subsoil (B horizon) were only 28. Thus the surface soil contained almost four times more phosphorus than the subsoil.

Another yield-regulating factor is soil structure. Subsoils in Michigan are more compact than surface soils (8). In naturally well-drained loam soil, average bulk density values for the plow layer were 1.32 gm/cc which represents a condition where high crop yields can be expected. The subsoil, however, averaged 1.52 gm/cc which is a relatively compact condition and, generally, too compact for optimum yields. Thus soil erosion invariably results in reduced yield potential.

Plant Nutrient Losses

Plant nutrient losses from Michigan soils can be calculated from data on average soil test levels (9). If 1 inch (300,000 lb.) of topsoil is removed by sheet erosion from a naturally well-drained loam soil, 6,000 lb. of organic matter are lost (6). In addition, 15 lb. of available phosphorus, 40 lb. of exchangeable potassium, 330 lb. of exchangeable magnesium, and 3 lb. of extractable sulfur are lost. These values represent immediately available nutrients. Total nutrients lost (including insoluble or unavailable nutrients) would be several times these values.

Large amounts of plant nutrients can be lost by erosion where fertilizer or manure were recently broadcast onto the soil's surface. Small fertilizer particles are generally lighter weight than soil aggregates; thus they are very easily transported by water.

Loss of Available Water

The available water-holding capacity of soil is related to its clay and organic matter content. When these materials are eroded away, the total water-holding capacity is reduced. Erosion also decreases the capacity of soil to absorb and store water. Water from summer rains is frequently lost when raindrops fall on hard and compacted soil material and, thereby, ponds or runs down slopes, causing even more erosion.

Deposition Damage

Soil erosion is a problem affecting all people because eroded material always moves somewhere. It is deposited in drainage ditches, water reservoirs, street gutters, parking lots, and in rivers and lakes. A freshly mud-coated landscape has little aesthetic value.

Increased Power Requirements

With reduced porosity, the soil is more compact and tillage requires more power. Also, when surface soil is washed away, the naturally dense subsoil is exposed, which requires more power to till than a well-conserved surface soil.

Reduced Income

It is evident that many interactions occur when soil erodes. The final product of soil erosion is reduced income for the farmer and higher taxes for all.

Causes of Soil Erosion

In the erosion process, soil particles are detached from the soil mass. The particles then move, but the distance is not always great, which explains why many people do not recognize that erosion occurs.

The effect of raindrops or sprinkler irrigation water hitting the soil is the first step in water erosion. The raindrops blast clods and shatter smaller granules, reducing them to even smaller particles and, in some instances, to the smallest possible dimensions of sand, silt, and clay.

A raindrop hitting a wet soil causes a slight depression with compacted soil material below the center. The force of the drop detaches minute particles from the soil mass and moves them away from the drop area. In a heavy rain on summer-fallowed soil, material is sometimes splashed a distance of 5 feet (1). Splash erosion, which is the first step in crust formation, occurs even on the level, lake plain soils, which many believe do not have a water erosion problem.

Figure 2. Rill erosion on fall-plowed hilly crop land in Ingham County.

Soil material tends to splash out in equal amounts in all directions on level land, but if there is a slope and the rain falls straight down, more than half of the splashed material moves downslope. When rainfall rates exceed the capacity of the soil to absorb water, some water collects in small depressions. If overflow occurs, there is runoff and erosion is possible.

If rain continues during the runoff, the flowing water is splashed repeatedly. This churns the water, and the breakdown of small aggregates continues. A small amount of flowing water carries a much greater load during a rain than would be possible without the splashing action. Thus, the erosive power of the loaded water is increased. Interestingly, the erosive power of pure water applied to soil so that *splash erosion* does not occur is extremely low because such water contains no abrasives.

Kinds of Water Erosion

There are four kinds of soil erosion caused by water: splash or raindrop, sheet, rill, and gully.

Splash erosion, as explained above, is the breakdown of soil aggregates and the scattering of small soil particles by falling raindrops. It is the first step in water erosion and the formation of soil crusts. The formation of a crust results in reduced ability of the soil to absorb water, and consequently, more water runoff.

Sheet erosion is the removal of a uniform layer of soil material from the surface by flowing water. The soil particles detached by splash erosion are carried away. The particles in moving water act as abrasives in detaching additional particles from the soil mass. Sheet erosion may go unnoticed until the lighter-colored subsoil appears at the surface.

Rill erosion is the removal of soil particles by water flowing in small but defined channels. The rills are only a few inches deep and do not interfere with normal tillage operations (Figure 2). Because of this, the severity of the rill erosion may go unnoticed for years.

Gully erosion is the continuation of rill erosion. Gullies cannot be corrected by normal tillage operations because equipment cannot easily cross the gullies (Figure 3). This kind of erosion is the most spectacular and extends through the plow layer into the subsoil. USDA Farmers Bulletin No. 2171 describes this kind of erosion and its control.

Figure 3. Shallow gully erosion on flat land in Saginaw County. Erosion is occurring where water enters road ditch. This resulted after road was improved. No vegetation was ever established on the ditch banks.

Factors Influencing Water Erosion

The erosion potential of any field is determined by five principal factors: climate, characteristics of the soil, topography, vegetative cover, and conservation practices. These factors have been related to each other in the soil loss equation (10,11):

$$A = R\,K\,L\,S\,C\,P$$

. . . where A is the average annual soil loss in tons per acre per year over a period of years; R is the rainfall factor; K is the soil erodibility factor; L is the length of slope factor; S is the gradient (steepness) of slope factor; C is the cropping-management factor, and P is the erosion-control-practice factor.

The components of R (rainfall or climatic factor) include the energy of the falling raindrops — the intensity and the duration of the rainfall. As the energy of raindrops increases, more soil particles are detached. Runoff increases as the intensity and duration of the rainfall increases. Therefore, the erosion potential increases.

The characteristics of the soil (K factor) which affect water erosion include texture, organic matter content, size and shape of aggregates, and the permeability of the least permeable layer (horizon) in the soil. Erodibility tends to increase with greater silt content and decrease with greater sand and clay contents. Organic matter holds individual particles together, thereby increasing the resistance to detachment. The shape and size of aggregates influences the infiltration rate and, therefore, erodibility. Erosion will not occur if the infiltration rate is greater than the rainfall. The permeability of the least permeable horizon affects erosion because rainfall must enter and move through the soil if runoff is to be minimal.

Soil erosion by water is affected by both slope length and gradient or steepness (L and S factors). As the slope length increases, so do the amount and velocity of runoff and the potential for erosion. As the slope becomes steeper, the velocity of runoff increases.

Vegetative cover (C factor) is very important in controlling erosion. Plants intercept the raindrops and prevent them from hitting the soil directly and detaching soil particles. They reduce the velocity of runoff and hold the soil particles in place. Plants also help to maintain a high infiltration rate. The kind and sequence of crops greatly affect the amount of erosion. Row crops are the least protective, grasses and legumes are the most protective, and small grains are intermediate.

The amount of soil exposed to raindrops and runoff varies with kinds of crops and time of planting. Fall-planted crops, such as wheat, protect against runoff of snowmelt and heavy spring rains. Spring-planted crops provide little protection against spring rains, but cover crops planted in the fall are effective. The yield of the crop is important. As yield increases, more vegetative growth is produced, resulting in more soil protection. Also, increased root numbers hold more particles in place.

Management of crop residues (C factor) also influences water erosion. Residues may be left on the soil's surface, incorporated near the surface, or plowed under. Residues are most effective when left on the surface where they shield the soil from raindrops, slow the velocity of runoff, and hold soil particles in place. With fall moldboard plowing, there are no residues to protect the soil during snowmelt and spring rains.

The amount of tillage (C factor) influences soil loss. The more tillage operations, the greater the compaction and the greater the runoff. When several tillage operations are performed, the soil remains unprotected for a longer time and erosion is more severe. Minimum tillage methods are effective in reducing soil erosion. With some methods (strip tillage, no-till), crop residues are left on the surface to provide protection while seeds germinate and plants are still small.

Conservation practices (P factor) vary in the ability to reduce soil loss. Tilling on the contour rather than up and down slopes reduces erosion because there are no man-made channels for the runoff water. Plow furrows on the contour act as miniature dams. Contour strip-cropping is more effective than contouring alone. The close-growing plants in alternate strips slow runoff velocity and trap soil particles carried by runoff from strips with row crops. Contour strip-cropping does not prevent soil from moving within the field but greatly reduces the amount moving off the field. Terracing is effective

Table 1. Potential soil losses from water erosion in corn fields harvested for grain or silage in central Michigan (6% slope).[1]

Dominant profile texture	Soil mgmt. group	POTENTIAL YIELD Grain (Bu/A)	Silage (T/A)	Slope length (ft)	Standing residue[2]	Chisel plow[3]	Mold-board plow[3]	Harvest for silage[2]	Tolerable loss
					TONS/ACRE/YEAR				
Clay loam	1.5a	105	17	100	4	5	7	7	3
Clay loam	1.5a	105	17	200	6	7	10	10	3
Clay loam	1.5a	105	17	300	8	9	13	13	3
Clay loam	1.5a	105	17	400	9	10	15	15	3
Loam	2.5a	110	17	100	6	7	10	10	3-4
Loam	2.5a	110	17	200	9	10	15	15	3-4
Loam	2.5a	110	17	300	11	13	18	18	3-4
Loam	2.5a	110	17	400	13	15	21	21	3-4
Sandy loam	3a	95	16	100	5	6	9	9	4
Sandy loam	3a	95	16	200	8	9	13	13	4
Sandy loam	3a	95	16	300	10	11	16	15	4
Sandy loam	3a	95	16	400	11	12	18	18	4

[1]*Assume – R rainfall value = 95, continuous corn, minimum tillage. Chisel plow use results in 50% cover. Moldboard plow leaves soil bare for up to six months.*

[2]*Spring plow*

[3]*Fall plow*

in reducing erosion because it shortens slope length, and in some types of terraces it reduces the slope steepness. Terraces should be constructed to conduct water on a non-erosive grade or to a stable outlet. Sod waterways frequently are an essential part of terrace systems.

The practical use of the soil loss equation is illustrated in Table 1. It shows three kinds of soils with different corn yield potential, four lengths of slope, and four crop residue management practices. The potential losses suggest that soil erosion by water is a greater problem in Michigan than many believe.

Soils vary in erosion susceptibility. In a continuous corn system, soil losses increase with length of slope and are well above the limits of "tolerable losses" established by the Soil Conservation Service even where slopes are as short as 100 ft.

The least erosion occurs where residues are left in the field over the winter months before spring plowing. Chisel plowing leaves approximately 50% of the residues on the surface which provides some protection. Using a moldboard plow in the fall results in more than a 50% increase in soil erosion over spring plowing.

Spring plowing fields that were harvested for silage is as good conservation as moldboard plowing in the fall but not as good as chisel plowing in the fall where the crop was harvested for grain.

The data suggest that silage corn should be grown on relatively level land where slopes are less than 2% and the length of the slope is less than 100 ft. Adding animal manure to silage corn fields in the fall or early winter significantly reduces soil losses.

Water Erosion Control Methods

Since rain or irrigation water falling on exposed soil is the first step in erosion, the best methods for control involve protecting the soil surface against the driving forces of the water. Anything that can be done to promote rapid growth and the establishment of a complete canopy of vegetation over the soil is likely to reduce the amount of erosion. Thirteen considerations here illustrate the principles of water erosion control.

Kinds of Tillage

The most common primary tillage tool in Michigan is the moldboard plow which surpasses all other implements in loosening compacted soil, incorporating crop residues, manure, fertilizer, or lime, and reducing opportunities for weed, insect, and disease problems. The major disadvantage to the moldboard plow is that it leaves the surface of the soil naked — completely exposed to the weather. Thus, the soil is in prime condition for water erosion.

Some farmers have switched from the moldboard to the chisel plow which is decidedly superior for erosion control because it leaves crop residues on the soil's surface. The residues protect the soil against both driving rain and water moving across the soil's surface. For a more complete discussion on advantages and disadvantages of each type of primary tillage tool, refer to MSU Extension Bulletin E-1041.

Tillage Time

Fall plowing is a major cause for accelerated soil erosion in Michigan. Because the amount of land plowed in late summer, fall, and early winter is increasing, the number of moderately and severely eroded fields is also increasing. From the soil erosion standpoint, fall plowing is not a desirable practice. If erosion is to be reduced to a minimum, fall plowing should be done only on the level fields of large farms which contain fine-textured soil.

Tillage Depth

Water percolates through compacted soil very slowly. As a result, runoff and erosion is excessive. Ideally, tillage should be deep enough to loosen compacted soil material. Deep tillage with a chisel plow or subsoiler on tile and ditch-drained soils helps only on excessively packed soil. The improved physical characteristics of such soils result in less erosion and increased crop yields.

Some farmers have not realized the benefits possible from deep tillage on compacted soils because the soil is repacked with secondary tillage tools and with herbicide application equipment. Also, some farmers do not appreciate how deeply the modern tractor can pack soil even though the soil is relatively dry. For details on the effect of tractors and secondary tillage implements on soil compaction, refer to MSU Extension Bulletin E-1042.

Minimum Tillage

"Minimum tillage" suggests no more tillage than necessary for rapid seed germination and a good stand. The definition implies that the minimal amount of tillage may be no-tillage. "No-till" or "sod planting" represents the most recent innovation in modern soil conservation. This kind of tillage leaves the residue from previous crops on the surface to protect the soil (Figure 4). Michigan has many areas well suited for this. It is obvious that the best conservation occurs when planting across the slope. This is also the situation for any tillage operation, whether it be deep, primary, or secondary. For more information on no-till corn, refer to MSU Extension Bulletins E-904, E-905, E-906, and E-907.

Minimum tillage methods are effective in reducing both water runoff and soil loss (2). Runoff from the minimum tilled watershed was less than one-half (41%) that of the conventionally tilled. Soil loss totaled only 6,854 lb. per acre for the 4 years, while loss from the conventionally tilled watershed was almost six times greater, totaling 39,433 lb. per acre.

Strip-cropping

Very few crop producers in Michigan use the concept of growing cultivated and close-growing or sod crops in alternate strips across a slope (Figure 5). In rolling topography, especially where slopes are long, this practice has merit because runoff from the cultivated area is retarded by the close-growing crop resulting in greater absorption of runoff and deposition of sediment.

Figure 4. No-till corn planted in sod. No-till methods represent the most recent innovation in erosion control in fieldcrop production.

Figure 5. Strip-cropping in Montcalm County. Corn and sod strips provide erosion control on 5 to 10 % slopes.

Strip-cropping is most effective where soils are permeable (not compacted) and where slopes are relatively uniform. In Michigan, strip-cropping on the contour is seldom possible because slopes tend to be short and irregular. However, field strip-cropping offers possibilities in some areas. Even in areas with short, irregular slopes, field strip-cropping reduces erosion.

Crop Residues

Today some people feel that crop residues should be ensiled, or converted to alcohol for use in an energy-starved world. Conservationists question such thinking because residues protect the soil's surface from rain and act as dams to slow water flowing over the soil's surface.

Severe erosion in Michigan occurs on many sloping fields where corn is ensiled. Producing high yields of both grain and crop residues and leaving the crop residues on the soil surface over the winter months is perhaps the oldest soil conservation method used in Michigan (Figure 6). This practice is still valid and probably prevents or reduces erosion more than any other single conservation practice.

Where corn is ensiled, livestock manure is also produced. Manure top-dressed to fields where corn has been ensiled is a well known conservation practice (Figure 7). The manure intercepts raindrops and reduces the velocity of runoff. Because manure contains a relatiavely high concentration of soluble nutrients, it should be used at rates which will not cause water pollution.

Crop residues are effective in reducing erosion, especially during the late winter and early spring months, but also have disadvantages. Soil temperatures in the spring are likely to be two or three degrees lower than where residues are removed or plowed down. This tends to delay seed germination, plant emergence, and early growth which may be a problem in the northern section of the state.

Cover Crops

Cover crops can be used to reduce erosion where crop residues are removed or sparse. A cover crop is one grown just to protect the soil. Oats planted in late summer-plowed fields provide a blanket to the soil while they are growing as well as after they are frozen. Rye is the old standby for those who do not fall plow. With modern herbicides, such use of rye is now feasible.

Fertilizer and Lime

Anything that can be done to produce high yields is likely to improve a soil conservation program. Both fertilizer and lime, when used wisely and based on a sound soil testing program, increase top and root growth. The aboveground parts of plants intercept the raindrops, thereby reducing splash erosion. The roots also decrease erosion potential by acting as barriers to moving water, holding particles in place, and bringing soil particles together into larger aggregates.

Pest Control

Anything that can be done to protect a crop and promote its growth is good conservation. Preventing weed, disease, and insect problems is good economics and good conservation.

Grass Waterways

Waterways paved with grass (Figure 8) should be used more extensively in Michigan because they protect areas where runoff water concentrates. But the success of a grass waterway depends on its proper design and maintenance; otherwise, gullies may rapidly develop.

The waterway should be designed for a peak runoff rate in a 10-year period. Because of this, it is well to consult a drainage engineer before attempting construction. Unless properly designed, erosion may be increased rather than reduced.

Across Slope Tillage

Tilling across rather than up and down the slope produces small dams to slow the water flow. Strict

Figure 6. Corn residues after the harvest of a high yielding crop. This picture shows 5,790 pounds per acre of residue. Little erosion is likely under these conditions.

Figure 7. Livestock manure topdressed to eroded soil in field used for silage corn is an effective method for preventing soil erosion.

Figure 8. Sod waterway in corn field prevents erosion. The best waterways are designed by engineers who can interpret crop requirements, soil variability and surveying and hydraulic principles.

contour tillage is not possible in many parts of Michigan because of short, irregular slopes. However, tilling across the slope as much as possible reduces erosion in the parts of the field where the tillage operations are on the contour.

Terraces

Terraces are hillside ridges, approximately on the contour, that dispose of excess water in a safe manner. A field is divided into separate drainage areas. The short, steep slopes separating the drainage areas are maintained in grass. The slope length is reduced and, with some types of terraces, the steepness of slope which is cropped is also reduced. Few terraces have been installed in Michigan because of the short, irregular slopes.

Water Diversions

Water diversions are channels or ridges constructed across the slope to divert excess water from one area to another where it can be disposed of safely. Because excess water is being carried to a drain, care must be used to prevent erosion of the ditch bank.

The success of conservation practices depends on proper design and installation. Soil Conservation Districts and the USDA Soil Conservation Service have a major responsibility to provide this assistance to landowners.

Summary and Conclusions

Soil erosion caused by water is increasing in Michigan. Many of the reasons for this are associated with increases in farm and implement size. Research in Michigan has demonstrated that the problem is minor some years but is great in others, depending on the rainfall characteristics.

Water erosion control involves many factors: depth, kind, time, direction, and amount of tillage. The use of conservation practices such as strip-cropping, returning crop residues, cover crops, grass waterways, terraces, and water diversions reduces soil loss from a field. Any practice which promotes rapid growth and high yield will help protect the soil against erosion.

With the increased interest in the creation and development of a high quality environment, soil conservation can be defined as "creative and concerned soil management." This definition places the responsibility for conservation upon land users which is necessary if they are to operate with a minimum of laws regulating their activities. It also recognizes the skills and innovative character of many land users and conservationists. Crop producers can achieve high yields and control erosion if they employ the proper conservation practices.

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