Conservation Methods for Soils of the ONTARIO-MOHAWK PLAIN and GLACIATED ALLEGHENY PLATEAU

Agriculture Information Bulletin No. 291 • Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE
in cooperation with
New York Agricultural Experiment Stations at Ithaca and Geneva

CONTENTS

Washington, D.C. Issued March 1965

CONSERVATION METHODS FOR SOILS of the ONTARIO-MOHAWK PLAIN and GLACIATED ALLEGHENY PLATEAU

By G. R. FREE, *soil scientist, Soil and Water Conservation Research Division, Agricultural Research Service* [1]

Agriculture is changing rapidly, and new practices in soil and water conservation are continually being developed for different land resource areas. The U.S. Department of Agriculture, in cooperation with the New York State Agricultural Experiment Station at Geneva and Cornell University Agricultural Experiment Station at Ithaca, has conducted research on soil and water problems and related studies on two land resource areas—Ontario-Mohawk Plain and the Glaciated Allegheny Plateau—at Geneva, Marcellus, and the Arnot station near Ithaca. The research at the Arnot station and Geneva was ended in 1955 after nearly 20 years, but it is still underway at Marcellus.

Fifty-one percent of the land area of the Ontario-Mohawk Plain is classed as cropland and 10 percent is classed as pasture; corresponding values for the Glaciated Allegheny Plateau are 23 and 24 percent, respectively.

The information given in this bulletin is based on the results of the research at these stations and is applicable to the land resource areas listed above that occur in small portions of New Jersey and Ohio and in larger areas in New York and Pennsylvania. The purpose of the bulletin is—

(1) To identify the major soil and water conservation problems in the Ontario-Mohawk Plain and the Glaciated Allegheny Plateau;

(2) To discuss principles of soil and water conservation; and

(3) To point out how these principles may be applied in developing efficient conservation practices on farms.

GENERAL DESCRIPTION OF THE AREA

The Ontario-Mohawk Plain and the Glaciated Allegheny Plateau comprise some 21.5 million acres. These two land resource areas are roughly delineated on the accompanying map (fig. 1), and their important characteristics are listed in table 1.

Elevations range from about 250 feet, along the lakes in the north, to 2,300 feet, on the higher hills in the south. Differences in elevation and in distances from large bodies of water affect the average length of growing seasons, which ranges from 110 to 165 days. Annual precipitation, favorably distributed on the average for most crops grown, ranges from 28 inches along Lake Ontario to 35 to 45 inches inland. Winter conditions prevail from late October through April and produce an average annual snowfall ranging from 50 to 100 inches.

[1] Also associate professor of soil technology, Cornell University, Ithaca, N.Y.

The author wishes to acknowledge the work of John Lamb and Everett Carleton, who were at Arnot station and at Geneva, respectively. The author's efforts were centered at Marcellus.

TABLE 1.—*Size and description of Ontario-Mohawk Plain and Glaciated Allegheny Plateau*

Area	Size	Type of farming	Topography	Dominant soil materials	Representative soil series and phases
	Million acres				
Ontario-Mohawk Plain:					
Lake Plain	2	Intensive; tree fruits and vegetables important.	Nearly level to gently sloping.	Mostly water-sorted sand, silt, and clay deposits.	On sand: Colonie, Alton, well-drained; Junius, Altmer, somewhat poorly and poorly drained. On silt and fine sand: Dunkirk, Amboy, well-drained; Collamer, moderately well-drained; Canandaigua, Wallington, poorly and somewhat poorly drained. On clay: Schoharie, well-drained; Lakemont, poorly drained.
Limestone-Till	4	Dairy and general; alfalfa, wheat, corn for grain, beans, and vegetables important.	Gently to strongly sloping.	High-lime till and outwash.	On till: Honeoye, Ontario, well-drained; Lima, moderately well-drained. On outwash: Palmyra, well-drained.
Glaciated Allegheny Plateau.	15½	Dairy dominant; limited acreages of potatoes, vegetables, and fruits.	Broad rolling ridge tops, valleys with steep sides and nearly level outwash floors.	Mostly acid till and outwash.	On till: Bath, well-drained; Mardin, Volusia, with pan layers that retard drainage. On outwash: Chenango, well-drained.

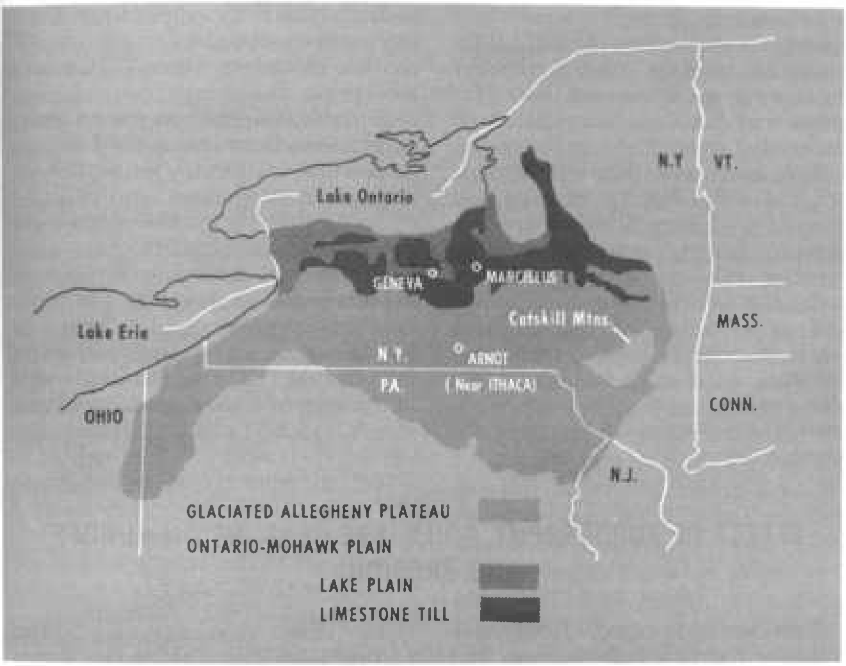

FIGURE 1.—Location of land resource areas.

CONSERVATION PROBLEMS

Conservation problems vary widely over the area and require different control measures or, more often, combinations of control measures to fit various situations. Some broad differences between areas are indicated in table 1 as differences in topography, soils, and types of farming. Since these and other factors vary within, as well as between, problem areas, the areas to be dealt with ultimately are the fields or slopes of individual farms.

Accelerated loss of soil by erosion is serious in many situations. Visual evidence of recent erosion is seen as rills on the eroded areas and as deposits of soil on highways, against fence rows and other obstacles, and in places where the slopes become less steep. Streams, ponds, and lakes made temporarily muddy by soil washed from the sloping land of a watershed or from the streambank itself are further evidences of erosion.

The greatest loss of soil in these areas occurs as small rills. If these rills develop into gullies, they present a hazard to farming operations and reduce the productive area within a given field.

Loss of topsoil, including organic matter and plant nutrients—native or applied—and the resultant reduction in yield, is only a part of the erosion damage. Removal of this most valuable part also decreases the soil depth available for moisture storage and root growth, and causes crop yields to decline. As erosion progresses and the plow layer is mixed and diluted with subsoil material, serious crusting and a decrease in the soil's capacity to absorb water may result. This tends to increase runoff, thereby decreasing moisture available for crops and for deep percolation on the eroded area.

Splashing and flowing water is not the only agency moving soil downhill. Every tillage operation, except plowing across the slope turning furrows uphill, tends to make the topsoil thinner on knolls and upper edges of fields. Each tooth of a spring-tooth harrow, for example, carries 12 pounds of soil along when moving *down* a moderately steep slope of Honeoye silt loam, but only 5 pounds when moving *up* the same slope. The resultant net movement downhill adds to soil losses resulting from erosion.

Conservation of water to meet short periods of drought, drainage to remove temporary excesses, and the safe management and disposal of water flowing on the surface are problems in many parts of the area. There is an increasing interest in supplemental irrigation for high-value crops, particularly where soils are droughty and a supply of water is available. This is especially true in the area of lowest growing-season rainfall along Lake Ontario.

EFFECT OF TOPOGRAPHY, SOILS, AND SEASONS ON RUNOFF AND EROSION

Erosion and runoff from bare soils are functions of steepness and length of slope, soil characteristics, and nature of past and current soil and crop management practices, as well as rainfall distribution, amount, and intensity. The average effect of doubling the steepness of slope, keeping all other factors the same, is to increase erosion by two to three times. The corresponding effect of doubling slope length, at least up to 400 feet, is to increase average erosion per unit of area by 40 percent.

When measured erosion losses from standard treatments, such as fallow, on a range of soils are reduced to conditions of average rainfall, slope steepness, and length, the soils can be ranked according to their relative erodibility. These data are available for four soils in the problem areas discussed here. The soil ranking high in erodibility is the Collamer silt loam, eroded phase (Lake Plains), at Geneva. Ontario loam and Honeoye silt loam (both Limestone-Till) at Marcellus and Geneva, respectively, rank medium on the national scale. Bath very channery silt loam (Allegheny Plateau) at the Arnot station ranks very low in erodibility even when all the stones above 2 inches in diameter are removed.

Stones have a very definite protective value. Removal of stones on the Bath soil increased erosion threefold and runoff 65 percent. Ninety-five percent of the soil washed off the plots from a stony Bath soil was fine enough to pass through a ¼-inch screen. Only 29 percent, or less than one-third, of the plow layer remaining passed through the same screen. Small erosion losses from the Bath soil, already high in stone content, may have more serious effects on productivity than greater losses from soils that are less stony. Therefore for this soil, average annual erosion losses should not exceed 2 tons per acre.

Research results for plots at all three locations in New York show that recovery of productivity under good management after excessive erosion is slow and incomplete. For example, on Honeoye soil at Marcellus, corn yields averaged 7 bushels per acre, or 8 percent less for the period 10 to 19 years after severe erosion (2 inches of soil removed in 4 years) than on adjacent plots where erosion had been controlled for the whole 23-year period of study. Management, including fertilization, was the same for all plots except during the first 4 years, when the differential erosion occurred. Too often, the yardstick used for measuring effects of erosion on productivity was yield alone, when it should be yield relative to that on comparable areas with similar management but where erosion was controlled.

It should be apparent from the discussion thus far that an inventory or survey showing soil type, slope, and other factors, is essential for the determination of the erosion hazard on any specific area.

Amounts of erosion can vary widely from year to year. For example, erosion losses from fallow plots at Marcellus one year totaled 155 tons per acre, or more than a 1-inch depth of soil (fig. 2). This was nearly seven times the amount lost the previous year and more than three times the amount lost the following year. Such wide ranges in losses are due primarily to differences in amount and distribution of intense rainfall.

An index of the potential erosiveness of rainfall has been calculated from detailed data on the amount and intensity of precipitation. The use of index values permits comparisons of potential erosiveness of rainfall during different seasons and at various locations. The rainfall index for an average year, for example, is 80 for central New York, 175 for central Iowa, and 400 for southern Georgia. Since the rainfall index for Georgia is five times as high as for New York, this means that annual erosion losses would be five times as great, provided soil, slope, cropping practices, and other factors were identical.

Table 2 shows that high-intensity rains have occurred in all three subareas. Months of occurrence extended from late May through September.

FIGURE 2.—A typical installation to measure runoff from plots at Marcellus, N.Y.

TABLE 2.—*Examples of high-intensity rains at three New York locations*

Place and years of record keeping	High-intensity rains and date for a period of—							
	5 minutes		15 minutes		30 minutes		60 minutes	
	Amount	Date	Amount	Date	Amount	Date	Amount	Date
	Inches		*Inches*		*Inches*		*Inches*	
Arnot (1935–55)	0. 66	June 1936	1. 22	June 1936	1. 63	Sept. 1937	2. 12	Sept. 1937
Geneva (1936–55)	. 56	July 1952	1. 05	Aug. 1947	1. 94	Aug. 1947	2. 36	Aug. 1947
Marcellus (1937–63	. 61	May 1941	1. 04	July 1947	1. 78	July 1947	1. 95	July 1947

The tendency to farm steeper slopes in these northern plain and glaciated plateau areas than in those where the index values are much higher may be justified. But this does not mean that no hazard exists and that serious erosion does not occur (figs. 3 and 4). A recently published analysis of conservation needs in New York shows erosion as a dominant problem on about 3¼ million acres.

Average precipitation varies from month to month in each of the major land resource areas, but the variation from March through November is quite small (fig. 5). Annual totals were 32 inches of precipitation, 80 for erosion index value, 28 tons of soil per acre, and 12 inches of surface runoff water. Figure 5 also shows that the greatest erosion potential of rainfall, based on rainfall characteristics,

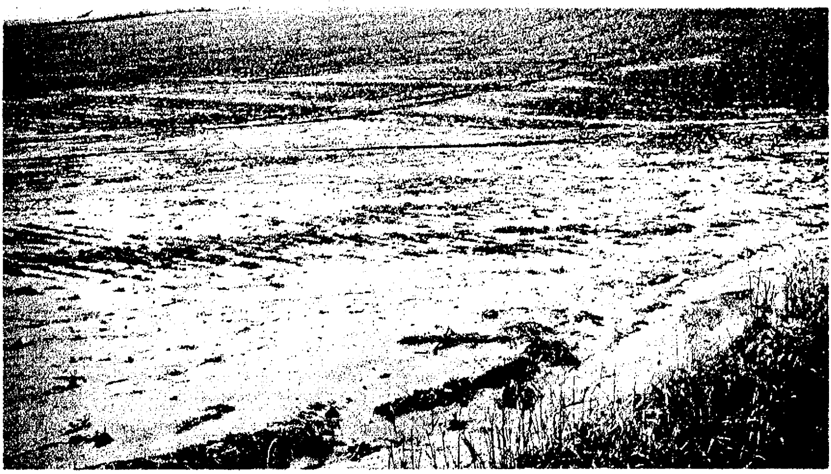

FIGURE 3.—Erosion from June storm near Geneva, N.Y. Note the length of slope exposed.

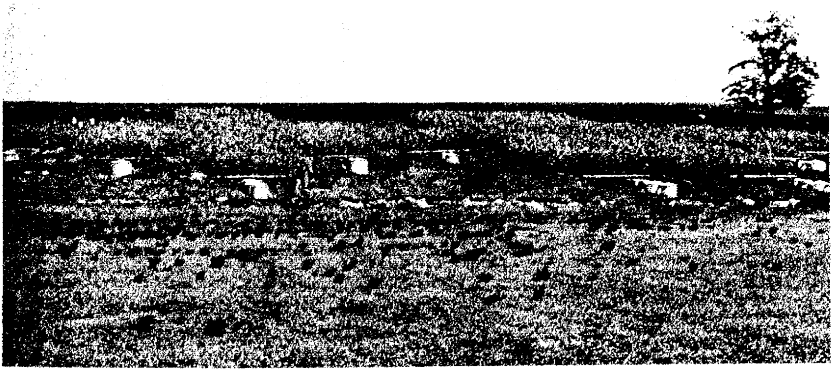

FIGURE 4.—Experimental plots at Marcellus, N.Y., field station furnish data on effect of length of slope on runoff and erosion.

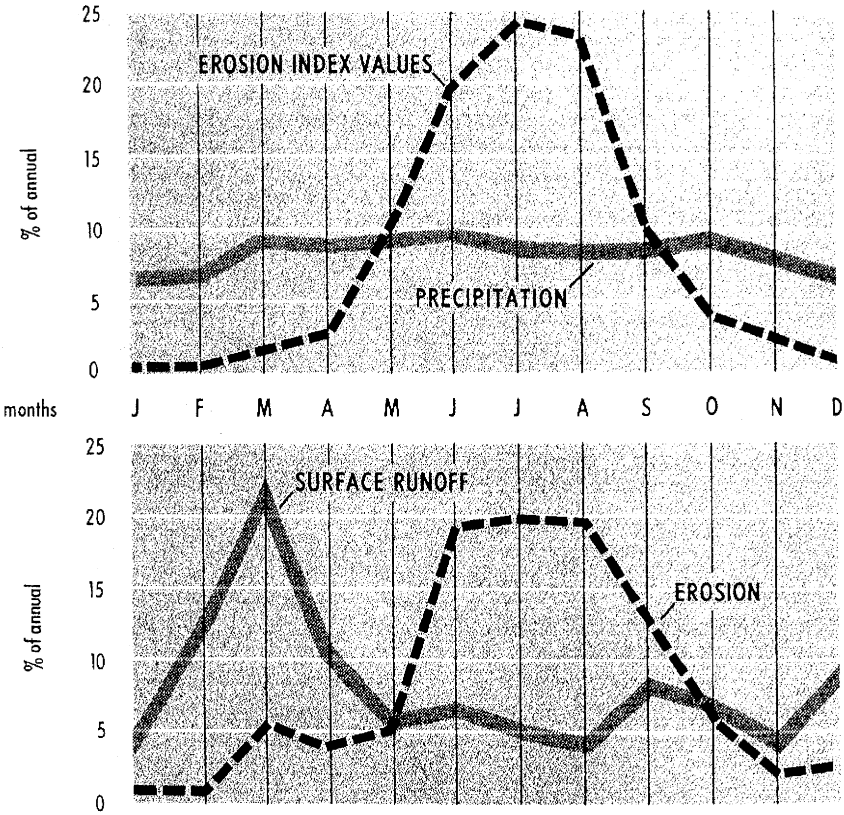

FIGURE 5.—Average seasonal distribution of precipitation, rainfall erosion index, erosion, and surface runoff from a fallow Lake Plain soil at Geneva, N.Y.

rises to a peak during the summer. Thus, two-thirds (20+24+23=67 percent) of the average annual erosion for soil that remains bare can be expected to occur in these three summer months. Close agreement of the actual seasonal erosion pattern and the index is readily apparent.

The seasonal pattern for surface runoff shows a peak in March, and thus differs greatly from the erosion pattern. The surface runoff peak is the result of melting snow and of rains of moderate to low intensity falling on frozen or nearly saturated soil. The energy for soil detachment and subsequent transportation is less prevalent at this time of year than later in the season, when rainfall intensities are higher. Therefore, only a relatively small increase in erosion is usually associated with the peak surface runoff on plots bare the whole year.

Water conserved by reduction of runoff during the time when crop use and evaporation losses are highest probably will have its greatest value for the crop. On the average, the discrepancy between rainfall and potential needs is greatest in July and August.

SOIL AND WATER MANAGEMENT PRACTICES FOR CONSERVATION

Fertilization and Liming

Rapid establishment and vigorous growth of plants through fertilization and liming not only increase crop production but provide better soil cover during the growing season. Larger crop residues provide further soil improvement. On Bath soil at the Arnot station, for example, better growth resulting from a small amount of fertilizer for continuous corn decreased both surface runoff and erosion losses during the growing season nearly 30 percent over an 11-year period as compared to unfertilized continuous corn.

Benefits of fertilization were even greater in a crop rotation than with continuous corn. Manure, lime, and superphosphate applied in a rotation of corn, oats, and clover on Bath soil reduced both surface runoff and erosion occurring during the growing season over an 11-year period nearly 60 percent as compared to the same rotation unfertilized. Although this was partly an effect of better cover resulting from more vigorous growth of all crops, it is believed that the primary factor was better soil structure or tilth for corn and oats after a good sod, with increased amounts of roots and other crop residues returned to the soil. Maintenance of a water-stable crumb structure at the surface and in the plow layer is an important contribution of good management.

An important part of any conservation practice or plan is a good soil fertility program. Lime and fertilizer applications should be based on crop needs and results of soil tests.

Cropping Systems

Under any cropping system erosion involves two processes: detachment and transport. When the soil is bare, small particles are easily detached by high-energy raindrop impact. Soil is usually bare at some time during most cropping systems or rotations. This temporary bare condition presents less of an erosion hazard than a continuous bare fallow plot. The difference in degree of erosion will depend to a great extent on the amount of crop residues and roots returned to the soil.

Increasing protection to the soil with a resulting decrease in erosion can be expected from crops in the order of intertilled crops such as cabbage; intertilled crops that later develop a good soil cover such as corn; small grains such as oats or wheat; and hay or pasture. The stage of plant growth also affects erosion. Small seedlings give little protection, as most of the soil surface is exposed to raindrop impact. As plants grow they give greater protection, not only through increased size of canopy, but also through greater root development.

This contrast of crops and their growth stages illustrates five kinds of erosion control associated with crops. These are:

(1) Protecting the surface of the ground against the impact of raindrops;

(2) Subdividing and reducing the velocity of water flowing on the surface;

(3) Using moisture from the soil profile for plant growth, thus making room for storage of additional precipitation;

(4) Binding together of soil particles by roots; and

(5) Improving and stabilizing soil structure.

Erosion under continuous corn at a low fertility level without a cover crop and with stover removed is about 70 percent of that from continuous bare fallow. If continuous corn is grown at a high fertility level with winter cover crop and with stover plowed under, erosion is decreased to 30 percent of that from continuous bare fallow. Thus, the erosion potential even under continuous corn can vary over a wide range, depending upon soil and crop management practices.

Erosion under rotation corn, the first year after a good sod crop, will be one-third to one-half less than under well-managed continuous corn.

Spring grains can usually be sown early enough to provide considerable soil protection before high-intensity rains occur. Winter grains, usually sown in early September, present an erosion hazard from high-intensity rains in late summer and early fall (see fig. 5). Too much delay in planting may lead to growth inadequate for winter survival.

Legumes and grasses for hay and pasture are the best crops for good soil and water conservation. They not only furnish nearly complete protection for the soil while growing, but they help maintain soil organic matter and structure. A dense and vigorous high-yielding stand provides greater benefits than a sparse runout meadow. Grasses and grass-legume mixtures provide greater residual benefits than legumes alone.

Under the usual dairy farm rotations, which consist of a high proportion of hay and pasture with a probable return of manure, the maintenance of organic matter and a good soil structure may require little attention. As more intensive systems are followed, with fewer sod crops and often without manure, soil organic matter and a satisfactory level of soil structure require more attention.

Under intensive row cropping, particularly with vegetable crops, the value of rotations in soil and water conservation is largely to reduce the period of time in which the soil does not have cover protection, or to allocate the bare periods to the time when the erosion hazard is less. Rotations may also have other important values such as disease and insect control.

Under the most intensive systems, emphasis must be placed on the conservation and return of crop residues and on the use of cover crops. Organic amendments such as straw, sawdust, or woodchips may be economically justified under certain conditions.

Emphasis is placed on soil organic matter and good soil structure because of benefits that can be measured in terms of increased yields and ease of soil and water management. Consideration of economics and efficiency should prevent overemphasis.

Cropping systems or rotations should be based on land capabilities. A well-drained and nearly level area can be cropped more intensively with less runoff and erosion hazard than erodible sloping fields.

Tillage

A finely pulverized seedbed greatly increases the erosion hazard, particularly if it is also compacted by implement and tractor traffic. From the standpoint of erosion control, the rougher and looser the seedbed the better. A well-prepared seedbed is needed in the immediate vicinity of the seed, however, to maintain adequate moisture for germination and seedling establishment. With some row crops, notably corn, the between-row area can be left entirely undisturbed after plowing. Not only does the rough, loose soil between rows help to reduce runoff, but also the large crumbs of soil resist transport if runoff does occur. This form of minimum tillage is known as plow-plant or wheel-track planting.

Farmers not wishing to plow-plant or wheel-track plant should at least keep tillage, seedbed preparation, and traffic to a minimum so that soil is not subjected to unnecessary pulverization and compaction. Excessive fitting operations and traffic, particularly when the soil is at a moderately high moisture level, can compact soils to the point where both the intake rate for water and crop yields are reduced. To some extent, the seedbed must be tailored to fit the crop. Seedbeds for small seeds cannot be as coarse and cloddy as for large seeds like corn.

Another general principle to be observed in seedbed preparation for soil and water conservation is the protection of soil from the direct impact of raindrops. Any kind of protection reduces crusting and partial sealing of the surface, and thus promotes a higher rate of infiltration. Where crusting has occurred, cultivation will usually promote more rapid infiltration again.

Seedbed preparation in which the residues of the preceding crop are left on the surface is widely used on the western plains for protection against both wind and water erosion. Adoption of this form of tillage is also increasing in the Southeastern States. There are hazards, however, when mulch tillage is used in New York for warmth-loving crops such as corn. Mulches of plant materials in any appreciable quantity tend to shade the soil and thus keep it both moist and cool. This is usually desirable in midsummer, but early in the season, soil temperatures sometimes may be cool enough to decrease the early growth of corn.

A more recent development has been to kill the sod with herbicides some time before planting. It is then possible, on some soils at least, to raise 100-bushel corn by planting directly in the killed sod with no plowing, fitting, or cultivation.

Contouring

On land that is moderately to strongly sloping or very erodible, supplementary conservation practices are usually necessary. They are usually necessary, also, for the more intensive systems on gentle slopes.

The first such practice to consider is contouring, either on the approximate contour, or on a planned drainage grade. When crops are planted on the contour, each row represents a miniature terrace holding water until more of it has had time to soak into the ground. Storage capacity depends on land slope and on the size of contour ridges or furrows.

The level contour layout is used only on permeable, well-drained soils. A slight continuous grade to point of safe water disposal is used on less permeable soils where surface drainage at a safe velocity is desirable. This also lessens the hazard of breakover when large storms occur.

Of the many examples of increased efficiency and crop yield benefits resulting from contouring, only one will be considered here. At Marcellus, N.Y., on a moderate slope of Honeoye soil, a comparison of contour vs. up-and-downhill tillage and planting for a variety of crops has been underway for more than 20 years (table 3). Management (except for direction of row) and fertilization for high yields has been the same for all plots.

Keeping soil, water, and plant nutrients in place pays excellent

TABLE 3.—*Annual yield benefit for contouring, expressed as a percentage of yields for up-and-downhill planting, on Honeoye soil at Marcellus, N.Y.*

Period	Annual benefit of contouring		
	Minimum	Maximum	Mean
	Percent	*Percent*	*Percent*
1942–45	−3	+19	+4
1946–52	+2	+22	+13
1953–62	+8	+38	+21

dividends. For example, during the period 1946–52, annual increases in yield from contouring ranged from 2 to 22 percent, with a mean increase of 13 percent. As previously mentioned, agricultural water has its greatest value when crops need moisture. Although serious prolonged drought does not often occur in the Ontario-Mohawk Plain and Glaciated Allegheny Plateau areas, short, dry periods are often broken by rains too intense to be held by ordinary up-and-downhill planting and tillage. Year-to-year benefits of contouring fluctuate widely, depending on the need for the conserved water. Despite this fluctuation, the benefits are increasing with time and thus reflect the long-term value of erosion control.

Stripcropping

As the conditions become too hazardous for control by contouring alone, alternate strips of intertilled crops, small grain, and hay may be used across the slope. The strips protected with close-growing vegetation spread out the runoff, filter out most of the soil, and absorb some of the water. As in the case of contouring, row grades may be level or gently sloping to close convenient waterways. Where straight strips are used, regardless of unevenness of topography leading to departures from a true contour or controlled row grade, the practice is called field-stripping rather than stripcropping.

Diversion Terraces

When the length of slope exceeds 300 to 400 feet, diversion terraces may be needed to reduce the length of slope effectively. Such terraces are often used on slopes above cropped areas to divert excess water. Many farmers in the Allegheny Plateau area are also using them at a closer spacing to intercept seepage flow along tight soil pan layers, and thus provide drainage.

Properly constructed and maintained terraces, including diversion terraces, are considered permanent erosion control structures. The ridge, channel, and a filter strip above the channel are seeded and left in sod in the case of diversions.

Any terrace should be designed to handle the probable volume of water involved at a safe velocity. A time of particular hazard is late winter and early spring, when channels may be filled with snow and ice.

Cropland Terraces

Gentle and moderately sloping areas that are intensively cropped, and where soil depth permits, may be completely terraced. Ridge and channel are cropped along with the interterrace areas. This procedure is not widely used in the area, but there are situations where it may be feasible. Anyone interested should give full consideration to possible difficulties with modern multiple-row equipment. Cropland terraces are not recommended for slopes in excess of 8 percent.

Cropland terraces do not eliminate the need for a management system that will control erosion between terraces. Without this, heavy rains may wash considerable soil into the channel. Unless the designed depth and capacity of the channel are maintained, the terraces will be overtopped. Under extreme conditions of interterrace erosion and without maintenance, the channels may eventually fill to the point where the pattern changes from ridge and channel cropland terraces to bench terraces.

There is an increasing interest in parallel terraces that eliminate the need for point rows and irregularly shaped buffer areas. Because few fields are uniform and regular with respect to topography, parallel terraces may require either excess deviation from optimum grade or land forming before terracing.

Land forming results in a permanent change of topography achieved by cutting high spots and filling low areas to give more or less a plane surface or series of plane surfaces. Obviously, the advantages are to be balanced against costs and the danger of exposing undesirable subsoils over too much of the area. Cutting and filling on some soils may lead to nonuniformity of growth and maturity of crops unless special productivity management measures are used. This nonuniformity is generally undesirable for many vegetable crops.

Outlets and Waterways

Although the control of water flowing in small rills is important and will greatly reduce erosion, the hazards involved in larger concentrations of water must not be overlooked. These places of concentration are often natural depression drainageways in fields. Graded terraces of any kind also serve to concentrate the flow of water. Safe disposal must be arranged in advance. Waterways and outlets should be shaped and seeded to provide a dense sod cover before concentrations of water are introduced. Liming and fertilizing as needed are very important. Topdressing with manure or straw may be helpful in getting rapid establishment of vegetation. Jute netting is another protective material that may be used. Subsurface drainage by tile may be advisable where continuous seepage flow endangers vegetation and constitutes a hazard to crossing with equipment.

Both waterways and outlets serve to carry the concentration of water down the slope to a natural stream channel or other safe disposal area. They are essential for contour-farmed or stripcropped fields, as well as for terraces and diversions. Safe, adequate outlets and waterways may necessitate cooperation between adjoining landowners.

U.S. GOVERNMENT PRINTING OFFICE: 1965 O—755-171