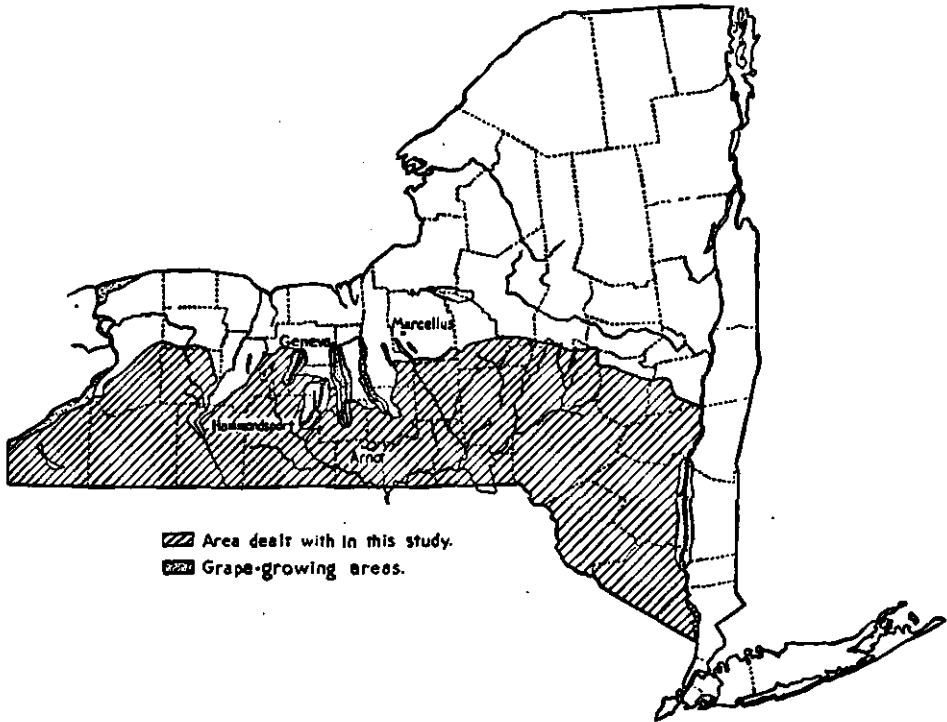


Experiments in the Control of Soil Erosion in Southern New York

John Lamb, Jr., J. S. Andrews, and A. F. Gustafson



Published by the
Cornell University Agricultural Experiment Station
Ithaca, New York

Received for publication March 1, 1944

CONTENTS

| | PAGE |
|--|--------------|
| Climate | 5 |
| Elevation and topography | 6 |
| Soils | 6 |
| Agriculture | 7 |
| The Arnot Soil Conservation Experiment Station | 7 |
| History of the Arnot Station lands | 7 |
| Purpose of experimental work | 8 |
| Experimental methods | 9 |
| What happened after New York forest lands were cleared? | 9 |
| Relationship of rainfall to soil erosion | 11 |
| Effect of intensity of rainfall on erosion | 13 |
| Seasonal occurrence of excessive rains | 14 |
| Relation of snow cover to soil erosion | 16 |
| Relation of slope of land to erosion | 17 |
| Length of slope | 17 |
| Steepness of slope | 18 |
| Stones protect the soil | 18 |
| Effect of protection by crops on losses of water and soil | 19 |
| Seasonal effects of crops on erosion | 20 |
| Loss of fine soil detrimental | 21 |
| Leaving residues on surface | 22 |
| Effect of fertilization of crops on losses of water and soil | 22 |
| Effect of contour planting and cultivation of potatoes on yields and on losses of water and soil | 23 |
| Effect of contour strip-cropping on losses of soil and water | 26 |
| Fertilization and good pasture management reduce loss of water and soil | 27 |
| Effect of past erosion on depth of surface soil, organic-matter content, and crop yields | 28 |
| Effect of pasturing woodlots | 29 |
| Vineyard experiments at Hammondsport | 30 |
| Erosion in the vineyards | 30 |
| Experiments in the control of erosion in vineyards | 31 |
| Measurement of loss of water and soil | 31 |
| Cover crops | 31 |
| Establishing new vines on badly eroded land | 32 |

SUMMARY AND RECOMMENDATIONS

1. Much of the rainfall from June through September comes as heavy showers or high-intensity rains. Bare land washes badly and needs protection (p. 14).
2. Erosion is likely to be severe on long, steep slopes.
 - a. Plow long slopes in strips across the slopes, and not all at once (p. 26).
 - b. Keep the soil-exposing crops on the gentler slopes (p. 18).
3. Stones protect the soil from erosion. Remove only the large, troublesome stones (p. 19).
4. Grasses, legumes, and small grains protect the soil. Seed these crops on the more erodible cropped slopes (p. 20).
5. Buckwheat and continuous corn permitted considerable loss of soil during June, July, and August, but land in meadow, oats, corn in rotation, and contour potatoes lost little soil. Erosive crops should be grown on the soils less subject to erosion (p. 20).
6. Leaving buckwheat stubble and straw on the surface reduced loss of water and soil; trashy cultivation should be practiced wherever feasible (p. 22).
7. Fertilization and rotation increase yields and reduce losses of water and soil. Therefore, maintain high productivity of the soil (p. 22).
8. Contour-planted potatoes lost less water and soil, and (average 1935, 1938, 1940-43) produced 15 bushels an acre more tubers than did those planted up- and downhill; corn 5 bushels more. Plant all crops on the contour, or as near it as feasible (p. 23).
9. Contour-strip-cropped land loses less water and soil than do long slopes in soil-exposing crops even if they are seeded on the contour (table 11). Divide long slopes into narrow strips (about 75 feet on a 15-per-cent slope) and alternate soil-protecting (meadow) with soil-exposing crops (corn or potatoes) (p. 26).
10. Well managed and fertilized, thrifty pastures retain water and protect the soil. Seed, fertilize, and lime, so as to maintain a high-producing, thick, soil-protecting sward (p. 27).
11. Past erosion has reduced the thickness of surface soil, and potato yields are correspondingly reduced. Soil washed away cannot usually be returned; hence rapid loss should be prevented lest yields be further reduced (p. 28).
12. Pastured woodlots have few seedlings growing to replace old trees. Fencing livestock out of the woodlots is imperative (p. 29).
13. Erosion on steeply sloping vineyard lands has been severe. Further rapid erosion must be checked if productivity is to be maintained.
14. Contour-planted grapes lost less water and soil and, in general, produced more fruit than did those planted up- and downhill. Plant new vineyards on the contour (p. 31).
15. Cover crops help to hold soil and water, but they compete with the grapes for moisture. Recommendations must be deferred until more information is obtained as to effects on yields and quality of the fruit (p. 31).
16. A mulch of straw or spoiled or wet-land hay aids materially in obtaining a stand and in promoting growth of new vines on badly eroded old vineyard lands. The mulching of producing vines increased yields at first. More information is needed concerning long-term effects on yield, quality of fruit, and winter injury caused by late fall growth.

EXPERIMENTS IN THE CONTROL OF SOIL EROSION IN SOUTHERN NEW YORK

JOHN LAMB, JR., J. S. ANDREWS, AND A. F. GUSTAFSON¹

The results of experimental work reported in this publication were obtained at two stations: (1) on land owned by Cornell University, adjacent to the Arnot Forest, seventeen miles southwest of Ithaca; and (2) on vineyard lands one mile west of Hammondspont. This applies to the higher elevations, the Appalachian Plateau and the Plateau Border, of southern New York, and also to the higher elevations of eastern New York and northern Pennsylvania, the areas cross-hatched in the cover illustration.

The data obtained at the Soil Conservation Experiment Station at Marcellus and at the New York State Agricultural Experiment Station at Geneva are reported in *Experiments in the Control of Soil Erosion in Central New York*, which is in process of publication. The locations of the various field stations are shown in the cover illustration.

CLIMATE

Summers in southern New York are moderately cool, particularly at the higher elevations. Winters are long and cold. The moderate summer temperatures are favorable for the growth of potatoes. The long-term average annual precipitation (rain and snow) is approximately 37 inches in central southern New York and about 40 inches in eastern New York. The nine-year average at the Arnot Forest (table 1) was 39.0 inches, or 4.2 inches more than at Ithaca. In the central part of the area, summer rainfall is likely to be light, and fairly long droughty periods are common.

TABLE 1. MONTHLY PRECIPITATION AND MAXIMUM AND MINIMUM TEMPERATURES AT THE ARNOT STATION AND AT CALDWELL FIELD AT ITHACA*

| Month | 9-year average precipitation, 1935-43 | | 8-year mean maximum monthly temperatures, 1936-43 | | 8-year mean minimum monthly temperatures, 1936-43 | |
|----------------|---------------------------------------|---------------|---|------------------|---|------------------|
| | Arnot | Caldwell | Arnot | Caldwell | Arnot | Caldwell |
| | <i>Inches</i> | <i>Inches</i> | <i>Degrees F</i> | <i>Degrees F</i> | <i>Degrees F</i> | <i>Degrees F</i> |
| January..... | 2.3 | 1.9 | 27 | 30 | 13 | 15 |
| February..... | 2.1 | 2.0 | 28 | 32 | 13 | 14 |
| March..... | 3.7 | 3.2 | 36 | 40 | 20 | 22 |
| April..... | 3.1 | 3.0 | 50 | 54 | 33 | 34 |
| May..... | 3.8 | 3.4 | 65 | 69 | 46 | 45 |
| June..... | 3.6 | 3.4 | 74 | 78 | 55 | 54 |
| July..... | 3.4 | 3.6 | 79 | 83 | 59 | 58 |
| August..... | 4.5 | 3.5 | 77 | 81 | 58 | 57 |
| September..... | 3.7 | 2.8 | 68 | 72 | 49 | 49 |
| October..... | 3.5 | 3.3 | 56 | 60 | 39 | 39 |
| November..... | 2.6 | 2.2 | 42 | 46 | 27 | 29 |
| December..... | 2.7 | 2.6 | 31 | 35 | 18 | 20 |
| Total..... | 39.0 | 34.8 | .. | .. | .. | .. |

*Caldwell Field at Cornell University Agricultural Experiment Station, Ithaca, New York; elevation 900 feet. Arnot elevation 1900 feet.

¹Respectively, Project Supervisor and Assistant Supervisor, Soil Conservation Service, Research, U. S. D. A., and Professor of Soil Technology, Cornell University. Captain Andrews has been on military leave since February 1942. Acknowledgment is made of the important work done by E. A. Engdahl, Assistant Agricultural Engineer and J. E. Chapman and Howard Wilson, Jr., Junior Soil Technologists, Soil Conservation Service, Research.

Methods of saving and holding water in the soil for the use of crops, therefore, are unusually important in this section.

ELEVATION AND TOPOGRAPHY

The elevation of southern New York is from about 1000 to more than 2000 feet. The area is cut by deep glacial valleys and by later stream valleys. Much of the farm land, therefore, occupies slopes of varying length and steepness. Many slopes are so long and so steep as to be subject to destructive erosion. The shallow-surfaced soils on the ridges wash badly on gentle slopes unless well-protected by vegetation. The well-drained gravelly soil in the valleys is relatively nonerodible, but much of it, especially that near the mouth of upland streams, is in danger of being buried by stones and gravel. This coarse material deposited by streams at flood stage covers the productive soil and renders it almost valueless for the time being. Occasionally later deposits of sand and silt cover the stones and thus reform a soil of some value. Hundreds of acres of these valley soils were so covered in July 1935 (figure 1).

SOILS

In southern and eastern New York the soils may be divided into three groups on the basis of their formation: (1) the uplands, (2) the valley fills, and (3) the stream bottoms or overflow lands. (1) The upland group comprises the largest acreage. The Lordstown, Bath, and Wooster represent the well-drained soils in the middle and western part of this area, and the Lackawanna soils are prominent to the eastward. Mardin, Canfield, and



FIGURE 1. HIGHLY PRODUCTIVE BOTTOM LAND BURIED BY STONES
DEPOSITED BY FLOOD WATERS

The productivity of good valley soils is greatly reduced by such a covering of stones.

Langford are of moderate depth on impervious subsoil strata, and Erie, Volusia, Chippewa, and Fremont are shallow-surfaced soils on impervious material. The two latter groups of soils do not take up water readily and, therefore, wash easily even on moderate slopes during heavy rainfalls. The Lordstown, Bath, Wooster, and similar soils would not be seriously erodible, except that so many of these soils are on long, steep slopes. Because these soils contain so little fine material, any considerable loss of it reduces productivity. On comparable slopes, the Lackawanna, Culvers, and similar soils of eastern New York are somewhat more easily eroded on the surface than are the Bath and Lordstown² soils.

AGRICULTURE

Dairying is the main agricultural enterprise in southern New York. In addition, intensive potato production is carried on in the cool climate on the hilltop areas of Steuben, Wyoming, and Allegany Counties, and to a lesser extent locally in numerous other areas. Cauliflower production occupies an important place in the Catskill Mountain region, and cabbage is grown in an area centering about Cortland County. Beans and cannery peas are grown on the plateau border in some of the western counties. Land in all of these crops, together with corn and vegetables and such fruits as peaches and grapes, is subject to erosion, especially if the slopes are long and steep. The acreage of hay and pasture is far greater than that of all the clean-tilled crops combined, but these latter crops are grown on some of the best soils, sometimes year after year, and often on somewhat steeply sloping lands.

THE ARNOT SOIL CONSERVATION EXPERIMENT STATION

The Arnot Soil Conservation Experiment Station is operated by the Soil Conservation Service (United States Department of Agriculture) in cooperation with the Cornell University Agricultural Experiment Station. The land on which the experimental work is conducted is adjacent to the Arnot Forest, owned by the University, on the boundary between Tompkins and Schuyler Counties. The Station is on the Appalachian Plateau at an elevation of about 1900 feet and is about 20 miles north of the New York - Pennsylvania State line (figure 2).

HISTORY OF THE ARNOT STATION LANDS

The land on which the Arnot Station is situated was cleared about 1870, and the E plots in 1934. Since 1870 the land has produced corn, potatoes, buckwheat, oats, wheat, and hay crops. Much topsoil washed off the slopes now covers what was original topsoil in the forest on the slope below. The farmed land, therefore, is stonier than in its virgin state, even though a former owner removed the larger stones. Fortunately, the rainfall in the Arnot area usually is not intense in the spring when the soil is unprotected by the oat crop. However, it is apparent that erosion might easily take place if wheat instead of oats were grown, because of the higher intensity of rains during August and September before wheat can protect the soil (figures 7 and 8, pages 13 and 15). This situation has undoubtedly contributed

²Descriptions of these soils are given in U. S. D. A. Soil Survey Reports of counties in the area, and in *Classification and Value of New York Soils*, by F. B. Howe (Cornell Univ. Agr. Exp. Sta., Bul. 619, 1935).



FIGURE 2. GENERAL LAYOUT OF THE ARNOT PLOTS

Runoff from the corn and adjacent plots, right foreground, goes down into the building in the center where water and soil are measured. Similarly water and soil lost from the plots beyond are measured in the tanks at the base of each plot. In the extreme right background are situated the plots on newly cleared land.

materially to erosion since the first quarter of a century after the land was cleared. Over the years, some manure has been used on the cropland. During the 12 years previous to the establishment of the station, moderate quantities of limestone, superphosphate, and mixed fertilizer were used for the corn and small-grain crops. On the whole, however, previous soil treatment on this land does not interfere with its use for experimental purposes.

PURPOSE OF EXPERIMENTAL WORK

The purpose of the experiments, the results of which are reported in this publication, was to obtain some idea of the extent of erosion, the type of rains that cause serious erosion, and the seasonal occurrence of such rains, and to compare common tillage and cropping practices with others that were new or that had been less commonly followed in New York. Holding water on sloping land until it may soak in for use by crops is an important phase of the work. Droughty periods, so severe as to reduce crop yields, occur rather frequently. Water that may be retained by improved cultural methods helps to maintain crop growth and crop yields in those seasons in which droughts occur. Holding water in the soil reduces the quantity that may run off over the surface. Water that is taken up by the soil does not cause erosion (except slip erosion after prolonged heavy rainfall). Only runoff water causes surface washing and gulying of the soil. Moreover, holding water on the land reduces the crests of floods and the resulting damage. Any water held in the soil increases the ground-water supply for wells, springs, and streams. It may be stated here that man's management, or mismanagement, of the land has lowered the ground-water level so greatly that many valuable springs of the earlier days now go dry in periods of below-normal rainfall. Wells must be dug deeper and deeper to obtain a dependable supply of water for farms, and many former all-year streams go dry nearly every summer. Such streams no longer can be depended on as a water supply for stock,

and fish and other forms of water life are adversely affected, if not killed, during periods of low rainfall.

Experimental methods

The precipitation was measured throughout the year with standard recording-type rain and snow gauges and old-type hand-measuring gauges as a check. More than one gauge of each type was used at each station, and records were obtained for all storms. The entire loss of water and soil was caught from plots 36 to 145 feet by 6 feet. The sides and upper ends of these plots were formed by steel borders projecting approximately 4 inches above the surface of the soil and extending 8 to 14 inches into the soil. A covered gutter and flume at the bottom of the slope led the runoff into tanks to be recovered and weighed. The runoff from the larger plots at the Arnot and Hammondsport Stations was caught in tanks by means of fractional divisors. The loss of soil is reported as pounds or tons of dry soil per acre. (figures 3, 4, and 5)

WHAT HAPPENED AFTER NEW YORK FOREST LANDS WERE CLEARED?

The early settlers cleared the forest from the land even on fairly steep slopes because the oxcart was the only freight service available and wheat could not be hauled long distances to the eastern cities. Wheat and other products for human consumption consequently had to be grown near the markets. That is why the early farmers cleared the land regardless of slope, and such virgin lands did produce good yields for a short time.

To determine how soon destructive erosion may start on newly cleared land a small area of timber was cleared on slope and soil similar to



FIGURE 3. DEVICES FOR MEASURING LOSSES OF WATER AND SOIL

At the right are the plots on the slope from which runoff water and soil come down into the metal funnels and pass into tanks within the building. Here water and soil are measured and weighed to determine the extent of losses.



FIGURE 4. INTERIOR OF THE BUILDING SHOWN IN FIGURE 3

Here Captain Andrews is recording the weight of soil in the drum being weighed by Mr. Chapman. The tanks at the left receive the water and soil from the plots through the funnels and pipes shown on the uphill side of the building in figure 3.



FIGURE 5. CATCHMENT TANKS FOR WATER AND SOIL FROM PLOTS SIMILAR TO THOSE SHOWN IN FIGURE 2

The water and soil are caught in the large tank from which the lid has been removed for inspection. A definitely measured fraction of the water and soil goes over into the first circular tank. When it is full and overflows, a fraction of the water and soil goes into the smaller tank at the left. Water and soil are measured to determine the loss of both.

adjacent land that had been cropped for three quarters of a century. The slope of the new land was 25 per cent and 132 feet long, as compared with a slope of 20 per cent and 72.6 feet long for the old land. More loss of soil and water would, therefore, have been expected from the steeper, longer slope of the new land. The losses of water and soil are given in table 2.

TABLE 2. LOSSES OF WATER AND SOIL FROM NEWLY CLEARED, AND FROM OLD CROP LAND DURING EXCESSIVE RAINS (BATH SILT LOAM)

| Date | Rainfall | | Plot* | Crop | Losses | |
|---------------|---------------|-----------------------------|----------|---------------------------|-----------------|---------------|
| | Total | Rate per hour in 15 minutes | | | Water | Soil per acre |
| | <i>Inches</i> | <i>Inches</i> | | | <i>Per cent</i> | <i>Pounds</i> |
| Aug. 19, 1936 | 1.30 | 3.20 | E4 | Plowed for wheat | 0.3 | 19 |
| | | | A8 | Fallow | 48.7 | 5,806 |
| | | | E2 | Rotation up- and downhill | 2.9 | 220 |
| | | | E1 and 3 | Rotation on contour | 1.4 | 40 |
| Aug. 21, 1936 | 0.94 | 2.64 | E4 | Plowed for wheat | 0.0 | 311 |
| | | | A8 | Fallow | 44.6 | 4,848 |
| | | | E2 | Rotation up- and downhill | 7.0 | 501 |
| | | | E1 and 3 | Rotation on contour | 5.4 | 85 |
| Sept. 3, 1937 | 2.04 | 3.04 | E4 | Plowed for wheat | 28.2 | 6,301 |
| | | | A8 | Fallow | 63.7 | 7,690 |
| | | | E2 | Rotation up- and downhill | 8.0 | 468 |
| | | | E1 and 3 | Rotation on contour | 0.3 | 2 |
| Sept. 4, 1937 | 2.70 | 4.64 | E4 | Plowed for wheat | 21.5 | 5,741 |
| | | | A8 | Fallow | 65.6 | 6,168 |
| | | | E2 | Rotation up- and downhill | 11.0 | 388 |
| | | | E1 and 3 | Rotation on contour | 0.5 | 3 |

*E plots, new land: E4, farmed with slope fallow (plowed for wheat) at time of rains; 25-per-cent slope; 132 feet long and 33 feet wide. Plot A8, nearby old land; kept fallow continuously; 20-per-cent slope; 72.6 feet long, 6 feet wide.

The first crop on new land (E 4) in 1935, was oats and barley. The grains were seeded late in the season, and gave only a fair yield (22 bushels per acre). No very erosive rain occurred after the stubble was plowed and before the fall wheat was seeded. In 1936 the wheat yield was high (37 bushels per acre), and even with erosive rains the loss of soil was low. The new land was still loose and very absorptive. In 1937 the wheat yield was low (17 bushels per acre). The reduction in yield was not due to the season, nor to the loss of soil, because the latter occurred after the crop had been harvested. The organic matter apparently reached a stage of decomposition where available nitrogen was deficient and soil-binding power reduced. The same new land nearby that was in corn, oats, and clover, strip-cropped in 1937, gave high yields of grain, and there was little loss of soil.

It is noteworthy that after three years of continuous wheat, losses by erosion were similar to those on old land. The same soil, however, cropped in a rotation of corn, oats, and clover since clearing lost little water or soil.

RELATIONSHIP OF RAINFALL TO SOIL EROSION

The mean annual rainfall (including water in snow) for south central and southwestern New York is 37.4 inches as an average for 11 stations covering from 19 to 74 years. For southeastern New York the mean

annual precipitation is 40.7 inches as an average for 16 stations, covering from 6 to 105 years.

Rainfall may vary considerably in amount within short distances. In August 1942, for example, 9.6 inches fell at one location on the Arnot Station and 6.2 inches at a point $1\frac{1}{2}$ miles away. At the same time, 2.5 inches fell at Hammondsport, which is 40 miles west of the Arnot Station. These data indicate the need for rainfall records at many additional locations.

Type of rainfall is far more important in its relationship to soil erosion than is the total annual precipitation. The degree of exposure of the soil and the time of the year that heavy rain comes often determine its effect on erosion (figure 6). The part of the precipitation that comes as snow obviously causes no erosion, except possibly as a result of runoff from melting snow.

Whenever rain falls faster than it can be absorbed by sloping soil, runoff follows; and if the soil is not protected, erosion occurs. Quick, heavy, dashing rains or thunderstorms during early summer before crops have produced a protecting cover cause severe loss of surface soil. If such heavy rainfall continues or if the total is large, gulying often takes place. The beating action of large raindrops on recently tilled, bare soils churns the finer soil particles into suspension. This suspension clogs the natural openings in the soil; also the particles may be rearranged and fitted together so closely as to check the intake of water by the soil. This causes heavy loss of the finest, most valuable part of the soil; this fine



FIGURE 6. AUGUST EROSION, TOMPKINS COUNTY, 1937

This long gentle slope had been plowed in preparation for seeding wheat. Much valuable topsoil was lost from this field.

material also is high in organic matter and plant nutrients. A dashing shower on wet soil is likely to cause severe damage, because wet soil does not take up additional water quickly and is readily brought into suspension. Similarly, rain, especially a beating one, on thawing, wet soil in the spring causes heavy loss of fine material, organic matter, and plant nutrients. In places the soil washes away as fast as it thaws. Sheet or surface erosion is severe under these conditions.

Effect of intensity of rainfall on erosion

Certain plots have been kept bare, without crops or weeds, to learn the effect of rains at any season of the year on losses of water and soil. A heavy rain falling in a short time, a high-intensity rain, causes more erosion than does the same quantity of water falling over a longer period, a low-intensity rain. A slow rain may all be absorbed with no accompanying loss of water or soil, but even a low-intensity rain falling on frozen soil or on soil the surface of which is already full of water, causes runoff, which usually carries soil with it.

The storm that caused the worst recorded flood in southern New York consisted of a series of moderate thunderstorms in early July 1935. The first showers saturated the surface soil, and the water from the succeeding showers nearly all had to run off because wet soil takes up additional water slowly. From 3 to 10 inches of water fell and poured down over the surface into the valleys. It is little wonder that flood waters reached new high levels. The effect of rains of high intensity on runoff and loss of soil at the Arnot Station is shown in figure 7. The rains that exceeded a rate or intensity of 1 inch an hour in 15 minutes caused losses of more than 1/2 ton of soil an acre. The two rains of an intensity of 4 inches an hour in 15 minutes caused losses of 7 tons of soil an acre. Soil ordinarily

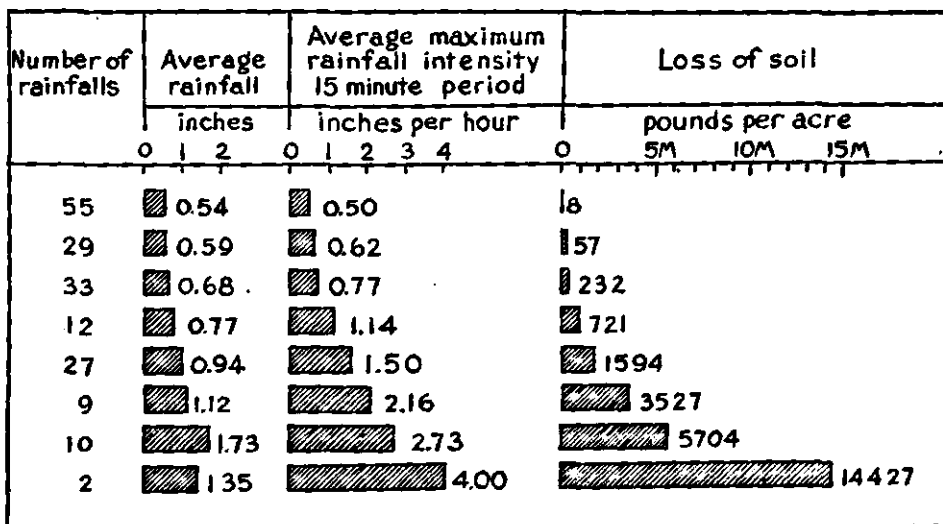


FIGURE 7. RELATION OF AMOUNT AND INTENSITY OF RAINFALL TO LOSS OF WATER AND SOIL

The rains are grouped in the order of losses of soil. The greatest loss occurred as a result of high-intensity rains. During the 8 years and 7 months ending December 31, 1943, 13 per cent of the 28 highest-intensity rains caused 57 per cent of the total loss of soil. Bath soil, clean-cultivated, fallow, slope 20 per cent, 72.6 feet in length.

is protected to some extent by crops during much of the year, but land other than meadow and pasture is exposed to erosion for varying lengths of time after plowing and until crops have made sufficient growth to afford protection.

Recording rainfall by months does not give a complete picture. All of the rain of a month may fall in a single week. If none falls during the remainder of the month, serious drought may develop, particularly during July or August when the need for water by crops is unusually great. Total rainfall at the Arnot Station for the past nine years as recorded by ten-day periods is shown in figure 8. Differences between the ten-day periods may be expected to decrease with additional years of records. The middle part of figure 8 shows the greatest intensity during the various ten-day periods. The intensity shown is the rate in inches of rainfall per hour for a period of 15 minutes or less. Generally speaking, the period of heavy loss of water and soil corresponds closely with the period of high-intensity rains, which at the Arnot Station is June, July, August, and September. To date, June and September have had the highest-intensity rains for 15-minute intervals, but many more rains of slightly lower intensity fell during the last period of July, and this period consequently shows the greatest loss of soil. It is important to bear in mind that these four summer months constitute the period of heaviest loss of soil in southern New York. Although the intensity of rainfall has been low in March and April, the loss of water by runoff has been higher than during the period of severe erosion. High runoff in these months results from melting of snow or from rainfall on soil that is frozen and therefore impervious, or on soil that is partially saturated. Temperatures are low; evaporation is slow; cold water is absorbed by the soil slowly; and the soil dries slowly. Runoff therefore is high.

Considerable variation, especially in the May-September rainfall may be noted, but it is evident that for this period, as well as for the others, intensity of rainfall has far more influence on losses of water and soil than has the total rainfall.

Seasonal occurrence of excessive rains

As pointed out in the preceding paragraphs, the intensity of rainfall plays a leading role as a cause of soil erosion. In table 3 are shown the number and the time of year of excessive rains at the four field stations and during the years covered by this experimental work.

Excessive rains³ usually cause runoff with loss of soil from unprotected

TABLE 3. EXCESSIVE RAINS AT FOUR SOIL CONSERVATION EXPERIMENT STATIONS IN NEW YORK

| Station | Years | Feb.* | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Total |
|----------------|-----------|-------|------|------|-----|------|------|------|-------|------|-------|
| Arnot..... | 1935-1943 | .. | .. | .. | .. | 8 | 11 | 14 | 4 | 1 | 38 |
| Geneva..... | 1936-1943 | .. | .. | 1 | 3 | 7 | 10 | 3 | 2 | .. | 26 |
| Hammondsport.. | 1936-1943 | 1 | .. | .. | 4 | 6 | 6 | 3 | 5 | .. | 25 |
| Marcellus..... | 1937-1943 | .. | 1 | 1 | 2 | 9 | 5 | 5 | 4 | .. | 27 |
| Total..... | | 1 | 1 | 2 | 9 | 30 | 32 | 25 | 15 | 1 | 116 |

*No excessive rains fell in January, November, and December during these years.

³The Weather Bureau describes an excessive rain as the accumulated amounts of precipitation for each 5 minutes during all storms in which the rate of fall equaled or exceeded 0.25 inch in any 5-minute period, or 0.30 inch in any 10-minute period, or 0.35 inch in any 15-minute period, etc.

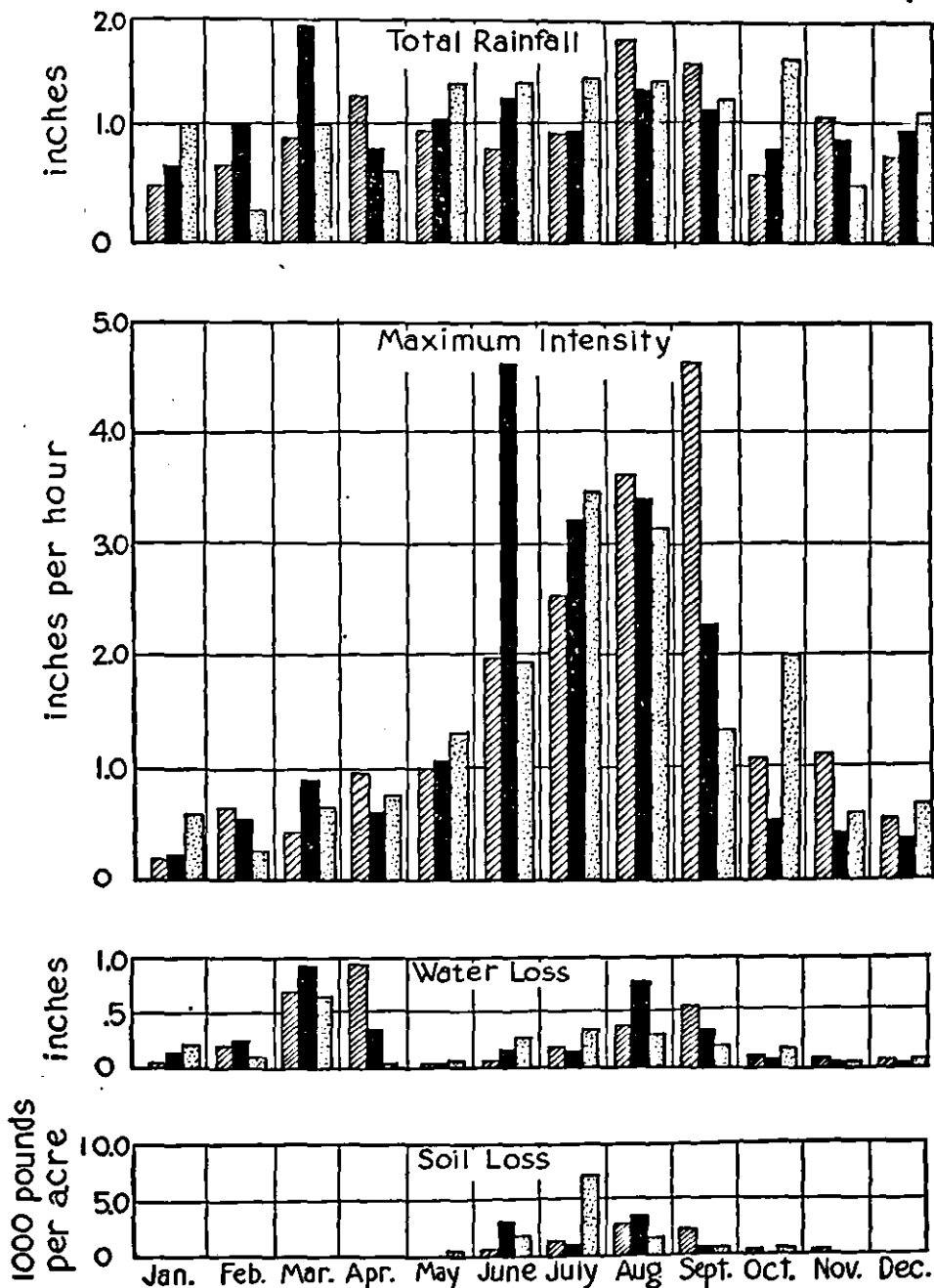


FIGURE 8. RAINFALL AND LOSS OF WATER AND SOIL AT ARNOT STATION, 1935-1943
 The upper two graphs show the average total rainfall by 10-day periods, and the highest 15-minute intensity during those periods.
 The lower graphs represent average total runoff and loss of soil during the same periods on fallow plots of Bath flaggy silt loam, 20-per-cent slope.

fields. It is interesting to note that no excessive rains have occurred from November 1 to June 1 during the period 1935 to 1943. Thirty-three of 38 excessive rains came in June, July, and August, the latter month having nearly one-half of the total. The heavy rains in August explain in a measure why southern New York had severe erosion on the steeper slopes during the early years when wheat was an important crop.

At Hammondsport the distribution of excessive rains is from May through September. Rainfall intensity can be determined only by means of the automatic, continuously recording rain gauge. Consequently this type of information is still somewhat meager for the State as a whole. The records available from the stations listed in table 3 cover too short a period to establish a general trend; however, the Weather Bureau records show the same seasonal occurrence of high-intensity rainstorms. Five hundred and thirty excessive rains fell at nine stations in New York that had records from 1903 through 1937. Only four of these were not in the May-October period, and 87 per cent occurred in four months, June-September.

Relation of snow cover to soil erosion

At the Arnot Station the soil usually is covered by snow throughout much of the five winter months and the soil may contain some frost even in November and May. Exposed slopes freeze deeper than do those protected by snow. Deep snow insulates the soil from freezing, and forest trees, especially conifers, retard the melting of snow by shading and by checking wind velocity. Moreover, snow absorbs rain and gradually releases it to soak into the soil.

Before the flood period of March 10-19, 1936, a uniform blanket of snow 20 to 30 inches deep in the forest insulated the soil against freezing even with air temperatures as low as -18° . Moreover, the shade of the forest trees delayed the melting of the snow ten days and thus tended further to reduce the crest of the flood. Many places in the fields were bare, or only lightly covered with snow, and on the K plots, the soil was frozen to a depth of 30 inches. The water was lost almost completely from both K plots, and K3, in potatoes the previous year, lost some soil. Grass and clover (table 4) on frozen soil, allowed all of the water to run off but no soil was lost. Where the land was not frozen, little water and no soil were lost.

No soil has been lost from any of the forest plots and very little water from the well drained Bath flaggy silt loam. A good forest or woodlot cover provides excellent conditions for absorption of water and for ero-

TABLE 4. INFLUENCE OF SNOW COVER AND VEGETATION ON LOSSES OF WATER AND SOIL, MARCH 10-19, 1936 (BATH FLAGGY SILT LOAM)

| Plot | Average slope | Vegetative cover | Soil condition | Depth of snow March 9-March 19 | | Runoff | Loss of soil per acre |
|------|---------------|----------------------|----------------|--------------------------------|--------|--------|-----------------------|
| | | | | Inches | Inches | | |
| K3 | 13 | None (potatoes 1935) | Frozen | 13 | 0 | 7.86 | 1,023 |
| K1 | 13 | Grass and clover | Frozen | 13 | 0 | 7.87 | 0 |
| A8 | 20 | None (fallow) | Not frozen | 60 | 44 | 0.630 | 0 |
| A9 | 20 | Grass and clover | Not frozen | 60 | 44 | 0.017 | 0 |
| F1 | 27 | Forest | Not frozen | 19 | 12 | 0.023 | 0 |

sion control. Forest on poorly drained Volusia flaggy silt loam lost considerable water as seepage and runoff during heavy thunderstorms. The storage capacity of Volusia soil for water is limited to the soil above the compact layer, which is found at an average depth of 10 inches.

The rain of August 13, 1942, caused severe local flood damage. Two watersheds, one 18 acres of idle land, and the other 9 acres of woodland, received 6.25 inches in nine hours, 3 inches of which fell in one hour. The soil in both places was poorly drained. The data are given in table 5.

TABLE 5. RUNOFF AND RETENTION OF WATER, STORM OF AUGUST 13, 1942 (INCHES)

| Watershed | 9:36 p.m., end of storm | | 10:36 p.m., 1 hour later | | 11:36 p.m., 2 hours later | | 9:36 a.m., 24 hours later | |
|------------------------------------|-------------------------|----------|--------------------------|----------|---------------------------|----------|---------------------------|----------|
| | Runoff | Retained | Runoff | Retained | Runoff | Retained | Runoff | Retained |
| Idle lands | 2.60 | 3.65 | 3.11 | 3.14 | 3.18 | 3.07 | 3.36 | 2.89 |
| Woodlot | 0.75 | 5.50 | 1.75 | 4.50 | 2.07 | 4.18 | 2.89 | 3.36 |
| Reduction in runoff by woods . . . | 1.85 | ... | 1.36 | ... | 1.11 | ... | 0.47 | ... |

The effect of woods in retarding runoff is notable. Only $\frac{3}{4}$ inch of water of the $6\frac{1}{4}$ that fell had been lost from the woods at the end of the storm. The idle land, in contrast, had lost more than $2\frac{1}{2}$ inches of water, more than three times as much as had the wooded land. As already stated, this soil has an impervious layer and, therefore, has low capacity for holding water. Even though the woods had retained only approximately $\frac{1}{2}$ inch more water than the idle land at the end of 24 hours, the wooded area had retarded the runoff to an extent that might materially reduce the crest of floods at least on the upper part of watersheds.

RELATION OF SLOPE OF LAND TO EROSION

Both length of slope and steepness of slope strongly influence the amount of erosion that may take place on any set of soil and cropping conditions.

Length of slope

Whenever rain falls on slopes faster than the soil can absorb it or the vegetation can hold it, runoff takes place. Under these conditions, because more rain falls on long than on short slopes, more total runoff takes place from the longer slopes. As water accumulates on the lower part of the slope, it runs faster, and in so doing picks up and carries away more and more soil.

Losses of water and soil from slopes of different lengths are given in table 6.

The losses of soil from the shortest slope (36.3 feet) are unexpectedly large, greater than from the longest slope in 1936, 1941, and 1943. No explanation for this condition is apparent. The greater loss of soil from the long slope than from the intermediate one is in line with the results at Marcellus and elsewhere.

These lengths of slope are really strip widths. This work, therefore, shows that strips 72 feet wide under these conditions are more effective in holding the soil than are 145-foot strips. On slopes of 15 to 18 per cent on well drained soils that are well supplied with organic matter, or that

TABLE 6. LOSSES OF SOIL AND WATER FROM APPROXIMATELY THE SAME DEGREE OF SLOPE AND THE SAME SOIL, BUT FROM DIFFERENT LENGTHS OF SLOPE AT THE ARNOT STATION (BATH FLAGGY SILT LOAM)*

| Years | A3, 36.3 feet | | A5, 72.6 feet | | A4, 145.2 feet | |
|---------|------------------------|---------------|------------------------|---------------|------------------------|---------------|
| | Soil | Water | Soil | Water | Soil | Water |
| | <i>Pounds per acre</i> | <i>Inches</i> | <i>Pounds per acre</i> | <i>Inches</i> | <i>Pounds per acre</i> | <i>Inches</i> |
| 1935 | 10,011 | 3.08 | 8,509 | 1.86 | 13,955 | 1.84 |
| 1936 | 16,168 | 1.79 | 8,541 | 0.99 | 14,156 | 0.96 |
| 1937 | 9,957 | 4.90 | 6,523 | 3.11 | 11,862 | 3.98 |
| 1938 | 6,910 | 3.12 | 4,446 | 1.89 | 8,129 | 2.36 |
| 1939 | 11,176 | 3.42 | 9,782 | 2.52 | 14,114 | 2.48 |
| 1940 | 8,050 | 2.09 | 3,433 | 1.14 | 14,127 | 0.79 |
| 1941 | 3,684 | 1.14 | 2,010 | 0.71 | 3,433 | 0.72 |
| 1942 | 8,795 | 5.38 | 3,062 | 2.88 | 5,607 | 2.71 |
| 1943 | 2,847 | 1.50 | 701 | 0.62 | 805 | 0.41 |
| Average | 8,723 | 2.93 | 5,225 | 1.75 | 9,576 | 1.81 |

*See figure 1 for additional details.

have a high proportion of flat stones, strips about 100 feet in width are suitable for long rotations with a soil-exposing crop occurring only once in five years or more. With shorter rotations, however, or with fewer stones, narrower strips protect the soil to better advantage.

Steepness of slope

The speed of flow on steep slopes enables the water to pick up and carry greater quantities of soil than on gentle slopes. The effect of steepness⁴ of slope on loss of soil and water is shown in table 7. The 18.3-

TABLE 7. EFFECT OF DEGREE OF SLOPE ON LOSS OF WATER AND SOIL

| Slope | Loss of water | Loss of soil |
|-----------------|---------------|------------------------|
| <i>Per cent</i> | <i>Inches</i> | <i>Pounds per acre</i> |
| 8.7 | 1.31 | 3,499 |
| 18.3 | 1.99 | 6,505 |

per-cent slope faces the southeast and received an average of 24.2 inches of rain from May through October; the 8.7-per-cent slope, which is exposed to the northwest, received 22.6 inches. The average annual soil loss from contour-cultivated corn on a slope of 18.3 per cent has been 6505 pounds per acre, as compared with 3499 pounds per acre from an 8.7-per-cent slope. The major part of this difference is probably due to the difference in slope.

STONES PROTECT THE SOIL

A study of the effect of stones in protecting the soil from erosion was made. A slope of 20 per cent, nearly one-half of whose surface was covered with flat stones, was used in this experiment. Stones more than two inches across were removed (figure 9) from one portion of the slope, and on a similar area the stones were left undisturbed. The effect of removal is shown in table 8.

Removal of the stones nearly doubled the loss of water and tripled losses of soil during the six years of comparison. The fallow soil with

⁴Slope, usually expressed in percentage, is the number of feet of vertical rise or fall in 100 feet of horizontal distance. Thus a drop of 10 feet in 100 is a slope of 10 per cent.

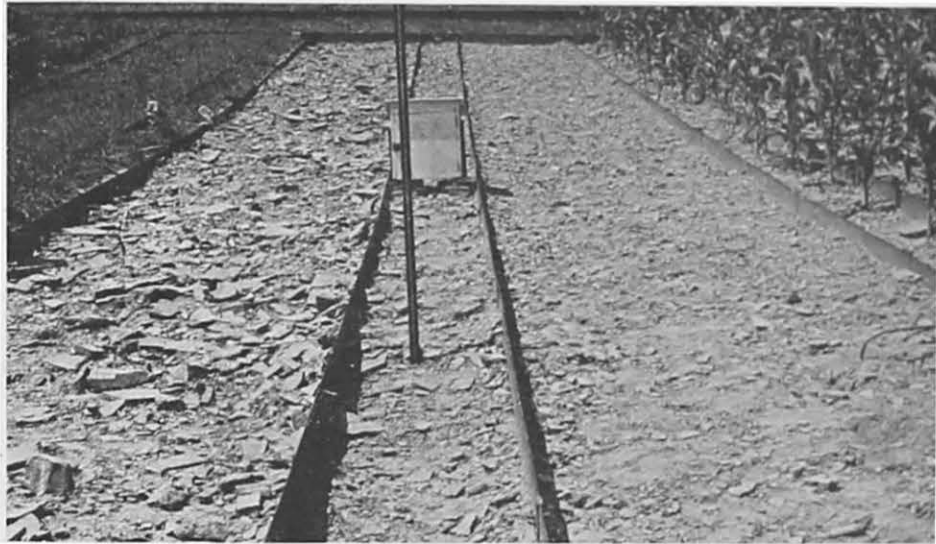


FIGURE 9. EFFECT OF STONES ON EROSION

On the right, the stones larger than 2 inches in diameter have been removed; on the left, the stones remain naturally. The stones protect the fine soil and hold it in place.

TABLE 8. EFFECT OF REMOVAL OF STONES ON LOSSES OF WATER AND SOIL, BATH FLAGGY SILT LOAM, SLOPE 20 PER CENT

| Year | Rain-fall | Plot A8, stones in place, fallow | | Plot A7, stones removed, corn | | Plot A5, stones in place, corn | |
|----------------|-----------|----------------------------------|------------------------|-------------------------------|------------------------|--------------------------------|------------------------|
| | | Water loss | Soil loss | Water loss | Soil loss | Water loss | Soil loss |
| | | <i>Per cent</i> | <i>Pounds per acre</i> | <i>Per cent</i> | <i>Pounds per acre</i> | <i>Per cent</i> | <i>Pounds per acre</i> |
| 1935..... | 22.7 | 15.0 | 17,127 | 13.8 | 16,150 | 8.2 | 8,520 |
| 1936..... | 20.4 | 13.2 | 30,179 | 8.7 | 17,495 | 4.8 | 8,546 |
| 1937..... | 31.3 | 20.1 | 26,973 | 18.8 | 18,886 | 10.2 | 6,522 |
| 3-year average | 24.8 | 16.1 | 24,760 | 13.8 | 17,510 | 7.7 | 7,863 |
| | | | | Fallow | | | |
| 1938..... | 20.9 | 18.1 | 14,646 | 23.6 | 22,491 | 9.0 | 4,446 |
| 1939..... | 16.8 | 15.4 | 8,212 | 25.0 | 24,746 | 15.0 | 9,782 |
| 1940..... | 23.0 | 8.2 | 5,496 | 19.6 | 32,730 | 5.0 | 3,433 |
| 1941..... | 14.1 | 8.2 | 6,710 | 13.2 | 19,984 | 4.1 | 2,010 |
| 1942..... | 30.1 | 19.2 | 12,346 | 26.0 | 38,747 | 9.6 | 3,062 |
| 1943..... | 23.1 | 7.8 | 3,942 | 14.6 | 13,892 | 2.7 | 701 |
| 6-year average | 21.4 | 12.8 | 8,559 | 20.4 | 25,432 | 7.5 | 3,906 |

stones undisturbed lost more water and soil than did similar land in corn. From these data, one may conclude that only the larger, troublesome stones, under these conditions, should be removed. Because these flat stones protect the soil from the beating action of rains and check the flow of water over the surface, less water and soil are lost.

EFFECT OF PROTECTION BY CROPS ON LOSSES OF WATER AND SOIL

Some crops such as meadow and pasture mixtures of grasses and legumes afford protection to the soil throughout the year and may be

termed *soil-protecting crops*. Others, such as corn, beans, potatoes, and many vegetables, fail to protect the soil during periods of serious erosion, and may be termed *soil-exposing crops*.

Plots including fallow, corn, small grain, and meadow were used to study losses of water and soil. The fallow plot was maintained for purposes of comparison with cropped plots, and for learning the extent of erosion on bare soil at all times. The losses of water and soil are given in table 9.

TABLE 9. EFFECT OF PROTECTION BY CROPS ON LOSSES OF WATER AND SOIL DURING THE GROWING SEASON, AVERAGE FOR THE YEARS 1935-43

| Plot | Crop and treatment | Loss | |
|------|--|-----------------------|-------------------------|
| | | Water | Soil* per acre |
| A8 | Fallow..... | <i>Inches</i> 3.81 | <i>Pounds</i> 19,583 |
| A5 | Continuous corn, 200 pounds 5-10-5..... | 1.77 | 5,239 |
| A14 | Potatoes†, 1000 pounds 5-10-5, sweet clover..... | 0.52 | 1,171 |
| A12 | Corn, oats, clover, 8 tons manure before clover..... | 0.40 | 441 |
| A10 | Idle, weeds, and clover..... | 0.29 | 394 |
| A9 | Meadow, fertilized..... | 0.18 | 17 |

*Bath soil—20-per-cent slope.

†1936 omitted because of sweet clover failure.

All crops were produced on the contour. As would be expected, the fallow plot lost most soil and water during these nine years. It is interesting that a rotation of corn, oats, and clover lost only $\frac{1}{4}$ as much water and $\frac{1}{12}$ as much soil as did continuous corn. The continuous-corn land became depleted of organic matter, although it was given 200 pounds of 5-10-5 fertilizer annually. In the rotation the soil was exposed only one out of three years, whereas the continuous corn afforded little protection.

At the Arnot Station, the intensity of rains is such that little erosion takes place in the spring on land being prepared for oats, and even less occurs in good clover.

Good, thick, thrifty meadow grasses and legumes protect the soil and hold water; consequently there is little loss of water and almost no loss of soil. Good meadows are among the best of the soil-protecting crops, and should be maintained in a thrifty condition on erosive, sloping land as much of the time as possible.

Idle land often is a menace from the standpoint of floods. Usually such land was abandoned following poor crops, and is covered only by a thin volunteer growth of weeds and grasses. This growth is usually so thin that it does not protect the soil nor hold water. Nearly all of the water, therefore, runs off and increases floods. Because of previous fertilization, however, a good growth of weeds, with some clover, held water and protected the soil fairly well.

Seasonal effect of crops on erosion

The effect of crops in protecting and holding the soil is shown in figure 10. This figure shows graphically the months when loss of soil occurred during the past nine years, 1935-43. Seasonal differences in the time when the crop protects the soil are evident. July and August account for

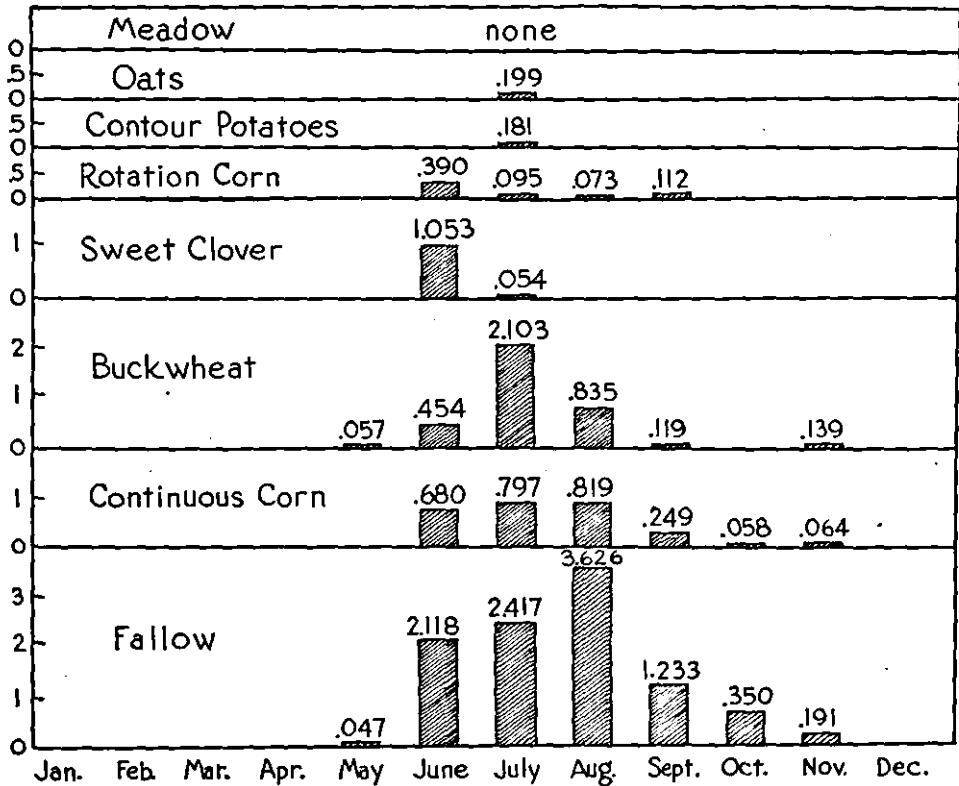


FIGURE 10. SEASONAL OCCURRENCE OF LOSSES OF SOIL, MAY 1935 TO DECEMBER 31, 1943. BATH SOIL
(Thousands of pounds of soil per acre)

and September on fallow land. As stated elsewhere, September erosion in times past has been serious with wheat.

Next to fallow, buckwheat lost the most soil in any one month, July. Continuous corn affords considerable protection; the loss is much less than on the fallow plot. The effect of the sod plowed for the rotation corn is to be credited with holding soil as compared with fertilized continuous corn. Added or accumulated organic matter also helps, as does the improved growth of rotation corn, as compared with continuous corn. It should be borne in mind that, as stated on page 9 under *Experimental Methods*, no water from above can reach the plots. The strip of iron protects them as would a diversion channel.

LOSS OF FINE SOIL DETRIMENTAL

The Bath soils on the Arnot field contain less than 30 per cent of material that passes through a sieve with 25 holes to the inch or 625 holes in one square inch. The larger particles of this finer material are coarse sand that is of little service to crops. Only a small part of the entire soil, therefore, is fine enough to hold water and to supply crops with plant nutrients. In contrast with the soil itself nearly all (95 per cent) of the material washed from the plots passes through the 25-mesh

sieve. Much of the soil lost by erosion is the part of the soil that supplies crops with plant food and that holds water for use by plants. If the fine particles are all washed away a "stone pavement" remains that cannot support thrifty growth of crops. The finest part of the soil must be held against erosion.

LEAVING RESIDUES ON SURFACE

In 1942 and 1943, buckwheat plots were tilled in such a way as to leave the stubble and the straw (750 pounds per acre) on the surface on two plots, which were then seeded; the other two were plowed, the seedbed prepared, and seeded in the usual manner. No residues were left on the surface, and the straw was not returned to this pair of plots.

The small amount of residue on the surface reduced the loss of water to less than one-half, and held the loss of soil to less than one-fourth of that from the land where the stubble was turned under. Records for two years show that the plots with residues plowed under lost an average of 2.4 inches of water and 2.2 tons of soil an acre, for the period June 10 to December 1 of each year. That some use may be made of mulching materials or trashy cultivation for erosion control in orchards and vineyards is indicated also by work at Hammondspport and Geneva.

EFFECT OF FERTILIZATION OF CROPS ON LOSSES OF WATER AND SOIL

Corn has been grown continuously without fertilization and for comparison, with 200 pounds of 5-10-5 an acre annually for the past nine years. Corn is grown also in rotation with oats and clover. Six tons of manure is applied to the clover sod before it is plowed for corn. In addition, 250 pounds of 20-per-cent superphosphate was put on for corn, and the same quantity for oats. Clover made poor growth in 1939 and, therefore, was of comparatively little benefit to the 1940 corn crop. The results are shown in figure 11.

Fertilization of continuous corn reduced the loss of water by one-third

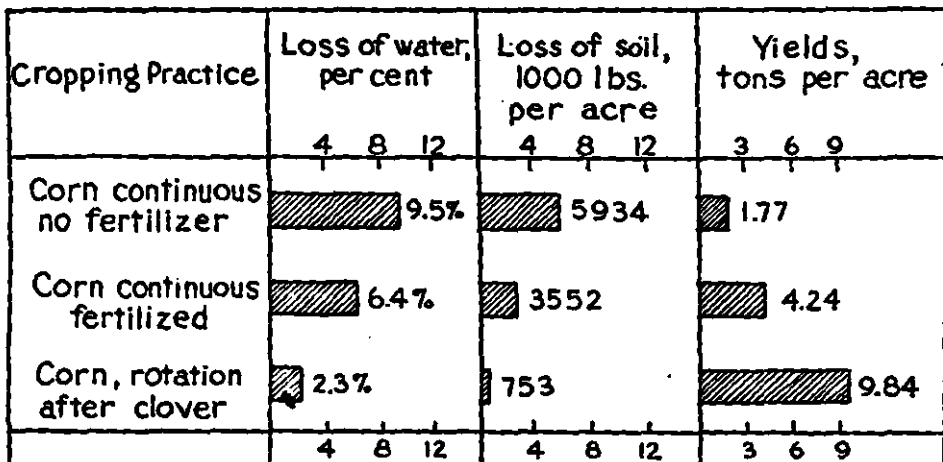


FIGURE 11. EFFECT OF FERTILIZATION AND ROTATION ON CROP YIELDS AND ON LOSSES OF WATER AND SOIL

(Rainfall, May through October, 23.14 inches as an average of 9 years, 1935-1943; slope 20 per cent; Bath silt loam.)

and of soil by two-fifths, and held these losses within reasonable limits. The rotated corn lost less than one-eighth as much soil as did the continuous, untreated corn. Fertilization more than doubled the yield of continuous untreated corn, but the fertilized, rotation corn yielded more than five times as much as the fertilized, continuous corn.

The reasons for these differences in yields and in losses of water and soil merit consideration. Soil under continuous cultivation for even so short a period as nine years becomes depleted of its more active organic matter, and plant nutrients and the granules of soil tend to break down and become smaller. Tiny granules or individual soil particles are more easily washed away than are larger granules. Moreover, an unfertilized, soil-exposing crop such as corn because of meager growth affords poor protection for the soil at any season of the year. Excessive, beating, summer rains readily churn the fine soil particles and tiny granules into suspension, and most of them are carried downhill by the runoff water. A soil cropped in this way easily becomes compacted, and some of the fine material churned into suspension lodges in and closes what openings remain in the surface of the soil. These facts help to explain the higher loss of water and soil from the continuously cropped land than from that in fertilized continuous corn and that in corn grown in a fertilized rotation.

Thrifty crops protect the soil against the beating action of rain drops, and the larger root system holds the soil together. Moreover, large yields leave organic matter in and on the soil as root and top-growth residues to help keep up the supply of active organic matter in the soil.

In this rotation corn followed clover sod. The grain crops and the meadow plants improved the tilth of the soil. The soil, being open and absorptive, took up the rainwater; consequently less water ran off and less soil was carried away. Also, the roots in the sod help to hold the soil against washing away. Moreover, the corn was benefited by the nitrogen left by clover, the superphosphate, and the manure, and through improved growth affords improved protection to the soil.

EFFECT OF CONTOUR PLANTING AND CULTIVATION OF POTATOES ON YIELDS AND ON LOSSES OF WATER AND SOIL

Experiments have been conducted to determine the comparative yields and the losses of water and soil from crops planted and cultivated up- and downhill and on the contour. The first experiment was set up on a slope of approximately 11 per cent on Bath silt loam, the plots being 21 feet wide and extending 311 feet up- and downhill. Potatoes were grown in 1935 and again in 1938 in a three-year rotation of potatoes, oats, clover. The results are shown in table 10.

The differences in loss of water and soil are striking. Nearly $\frac{1}{8}$ of the growing-season rainfall was lost from the up- and downhill rows and almost none from the contour-planted potatoes. Differences in loss of soil in 1935 are even more striking—14 tons an acre from the up- and downhill rows, as compared with 0.1 ton an acre from the potato rows on the contour. In 1938 the loss of water was not determined, but the loss of soil from the up- and downhill rows was more than $5\frac{1}{2}$ tons an acre, as compared with no loss of soil from the contour rows. This soil naturally contains many stones and only about one-third of fine material (29 per

TABLE 10. EFFECT OF CONTOUR PLANTING AND TILLAGE ON CROP YIELDS, MAY-OCTOBER RAINFALL AND DROUGHTY PERIODS

| Year | Crop | Number of tests | Crop yield per acre | | | Rainfall, May to Sept. | Periods of 10 days or more, rainfall less than 0.15-inch in 24 hours | | | | |
|------|----------|-----------------|---------------------|-------------|---------------------|------------------------|--|----------------|-----------------------------|----------------|------|
| | | | Contour | Up and down | Increase on contour | | Inches | Starting date | Days | Starting date | Days |
| | | | Bushels | Bushels | Bushels | | | May 10 | 25 | Aug. 14 | 13 |
| 1935 | Potatoes | 1 | 191 | 181 | 10 | 19 | May 10 | 25 | Aug. 14 | 13 | |
| 1936 | | 0 | ... | ... | .. | 16 | May 27 | 11 | July 4 | 19 | |
| 1937 | | 0 | ... | ... | .. | 26 | July 15 | 10 | Sept. 15 | 24 | |
| 1938 | Potatoes | 1 | 242 | 206 | 36 | 20 | June 13 Sept. 23 | 23 27 | Aug. 23 | 16 | |
| 1939 | Corn | 1 | 53 | 48 | 5 | 14 | May 10 June 14 July 14 | 11 15 13 | May 28 June 30 Aug. 9 | 16 13 15 | |
| 1940 | Potatoes | 4 | 120 | 97 | 23 | 21 | June 12 Aug. 13 Sept. 26 | 11 11 11 | July 9 Aug. 28 | 15 11 | |
| 1941 | Potatoes | 5 | 109 | 95 | 14 | 12 | June 16 | 14 | Sept. 11 | 21 | |
| | Corn | 1 | 51 | 46 | 5 | | | | | | |
| 1942 | Potatoes | 4 | 261 | 264 | -3 | 26 | | .. | June 4 | 13 | |
| 1943 | Potatoes | 8 | 192 | 184 | 8 | 17 | Aug. 15 | 12 | Sept. 5 | 26 | |

cent through 1-mm. sieve). Of the wash from the plots, 95 per cent passed through the 1-mm. sieve. Loss of the fine soil, therefore, is far more detrimental than from soils that consist mainly of fine material. The topsoil to a depth of about 7 inches weighs about 1000 tons an acre. About 20 potato crops, on the basis of these average losses from up- and downhill rows, will permit removal of all the fine material from the top 7 inches. The fine material is needed to hold water, organic matter, and plant nutrients, as well as to supply plant nutrients to crops. Without the fine material the soil is unable to retain the water that crops must have for growth.

Although neither 1935 nor 1938 was a dry year, there was an increase of 10 bushels an acre of potatoes in 1935 and of 36 bushels in 1938. Fairly long periods without ample rainfall occurred in 1938. It is during such times that the water held by the contour rows improves the moisture content of the soil, and enables the potatoes to make better growth than in the drier up- and downhill rows. In seasons of ample, well distributed rainfall with little loss by runoff, little difference in growth would be expected (figure 12).

A further experiment to study the effect of direction of potato rows on Mardin stony silt loam was begun in 1940. This soil has a tight or impervious layer at 15 to 18 inches below the surface. The rotation was potatoes, oats, and barley, 8 plots of each crop every year, or 24 plots in all. Six plots of each crop were on a slope of 10 per cent and two of each crop on a 20-per-cent slope. The yields of potatoes are given as averages of 8 plots a year in table 10.

The average annual increase for these four years is $9\frac{1}{2}$ bushels of potatoes to the acre for contour over up- and downhill planting. At a



FIGURE 12. CONTOUR AND UP- AND DOWN-HILL POTATO ROWS

Contour rows at left, the soil lost in 1935 (202 pounds an acre) is in 2-gallon cans standing on the silt box at the left. On the right are the up- and downhill rows. The soil lost (28,282 pounds an acre) in 1935 is in the 55-gallon drums on the right.

low price such as 30 cents a bushel for potatoes unharvested in the field the increase is worth \$2.85 an acre, or at 50 cents a bushel, \$4.95 an acre. Increased yields usually are obtained in droughty years when yields are lower than average and the price higher than usual.

These amounts appear exceedingly small, but consideration should be given to the fact that no added expense is involved, and that often there is a saving in the cost of power used on the contour, as compared with up- and downhill rows.

Much fine soil material was deposited in the weeds and grass below the up- and downhill rows by the runoff from the potato rows. In the early spring before the barley was sown on the area, such deposits were distinctly noticeable. There was little, if any, evidence of loss of soil from the contour-rowed bare potato land the following spring.

If the contour rows are on the dead level they will hold water ponded above the rows after heavy rains. Rains up to 2 inches have been so held. It is entirely possible that water from a period of successive rains might actually reduce the yield. Enough water might be held to interfere with digging. These difficulties can be avoided in large measure by giving the rows a slope of approximately 6 inches in 100 feet. It will, of course, be necessary to provide for safe disposal of this water at the end of the rows.

In another test, corn in 1939 and in 1941 produced 5 bushels (56 pounds of shelled corn) more grain to the acre on contour than in up- and downhill rows. In 1942 and 1943 there was no difference in yield of corn.

At College Park, Maryland, Hobbs⁶ measured the runoff caused by a thundershower from two 6-acre watersheds planted to corn. The runoff was six times as fast and three times as great from the watershed with the corn rows up- and downhill, as from the contour planted corn. The corn, which was growing actively, needed all the water that fell, yet much was lost from the up- and downhill rows. It has been noted that considerable runoff and erosion take place if one-fourth inch of rain falls in 15 minutes on bare soil. At the Arnot Station in the six years (1935-40) nearly one-third, and at Hammondsport one-fourth of the June, July, and August rain fell at intensities higher than one-fourth inch in 15 minutes. Much effort, therefore, is needed to hold on the soil an adequate amount of water to produce good yields.

⁶Data supplied in personal correspondence.

EFFECT OF CONTOUR STRIP-CROPPING ON LOSSES OF WATER AND SOIL

Contour strip-cropping means the growing of soil-exposing crops such as corn, potatoes, or buckwheat in relatively narrow strips across slopes on the level, or contour, alternated with strips of soil-protecting meadow, or small-grain crops seeded to meadow mixtures. The strip widths tested at the Station were approximately 50 and 100 feet. The rotation used in the strip-cropping experiment was potatoes, oats, and clover.

Under the soil, slope, rainfall, and cropping conditions at the Station, meadow lost no soil, and oats and potatoes on the contour lost only moderate quantities. The Lordstown soil is absorptive, and if the speed of runoff is decreased sufficiently the water is pretty well taken up; hence little runoff and little loss of soil occur.

Excessive rains occurred during all of the years of this experiment. It may be of interest to note that the only appreciable loss of soil in winter from potato land in contour strips occurred where there was no meadow between it and the catchment equipment. In other words, the soil washed from the potato land was caught and held by the meadow directly below it.

The strip-cropped area was compared with one plot of potatoes planted on the contour and one planted up- and downhill on the same soil and slope. Because of lack of area there were no duplicate plots, and only one crop could be grown each year. Potatoes, therefore, occupied the land only every third year. The losses of soil and water are given in table 11.

TABLE 11. EFFECT OF STRIP-CROPPING AND CONTOUR CULTIVATION ON LOSSES OF SOIL AND WATER

| Management* | Loss in growing season† | | Loss in winter season | | Total loss of soil per acre |
|-------------------------|--------------------------|---------------------------------|------------------------|---------------------------------|-----------------------------|
| | Water * <i>Inches</i> | Soil, per acre <i>Pounds</i> | Water <i>Inches</i> | Soil, per acre <i>Pounds</i> | |
| Strip-cropped: | | | | | |
| 51.8 foot strips..... | 0.29 | 345 | 16.03 | 1,254 | 1,599 |
| 103.7 foot strips..... | 0.41 | 292 | 16.28 | 1,863 | 2,155 |
| Contour-cultivated..... | 1.14 | 2,514 | 14.35 | 1,498 | 4,012 |
| Up- and downhill..... | 3.44 | 31,068 | 15.61 | 1,068 | 32,136 |

*Slope: upper two-thirds of plots, 8 per cent; lower two-thirds, 15 per cent. Slope 311.2 feet long. Rotation: potatoes, oats, and clover.

†Growing season: July through October 1935, May through October 1936 and 1937, Winter season: November through April 1935-1936, 1936-1937, 1937-1938. Rainfall: average of growing season, 21.9 inches; average for winter season, 17.6 inches.

Both widths of strip in this rotation of potatoes, oats, and clover held erosion within reasonable bounds; the 50-foot strip was slightly better than the wider one. The loss of soil from the contour-planted potatoes was about twice that of the strip-cropped land. The up- and downhill planted potatoes lost 3½ inches of rain during the growing season, as compared with 0.3-0.4 inch on the strip-cropped land. The loss of soil from the potatoes planted up- and downhill was about 16 times that from the strip-cropped land. Water from above was excluded. On the Mardin or Fremont types (with impervious subsoils) water from above should be removed by diversion terraces at frequent intervals, and the rows of intertilled crops should follow the approximate slope of the diversion channel.

FERTILIZATION AND GOOD PASTURE MANAGEMENT REDUCE LOSS
OF WATER AND SOIL

More than two-fifths of the crop and pasture land of southern and southeastern New York is in pasture. A thin stand of unthrifty pasture plants allows heavy rains to run off quickly and to carry soil from sloping lands, especially from the steeper slopes. The slope of the land used for the pasture studies was about 23 per cent.

A variety of pasture mixtures with wild white clover were used. The fertilized plots received the equivalent of 500 pounds an acre of 20-per-cent superphosphate and 100 pounds of 50-per-cent muriate of potash in 1935. The unfertilized area had been cropped before the Station was established, and had been treated with moderate quantities of superphosphate, lime, and manure. The untreated pasture, therefore, was superior to the average untreated pasture of this area. During the years 1936, 1937, and 1938, the fertilized soil produced two and one-half times as much feed as did the unfertilized soil. Yield was determined in terms of dry grass and clover. After 1936 no soil was lost from any of the plots, and only small amounts of water. Fertilization, by producing a thicker sward and more plant cover, reduced the loss of water, but the loss was well controlled on all of these plots (figure 13). To maintain yields, it will be necessary to repeat the treatment with superphosphate, and perhaps with potash also, every four or five years.

However, these plots were on Bath stony silt loam, an absorptive soil. Pastures can hardly be expected to hold all the rainfall on slopes of the Mardin, Canfield, or Langford soils of moderate drainage, or on the Erie, Volusia, or Fremont, shallow, slow-draining soils of southern New York.

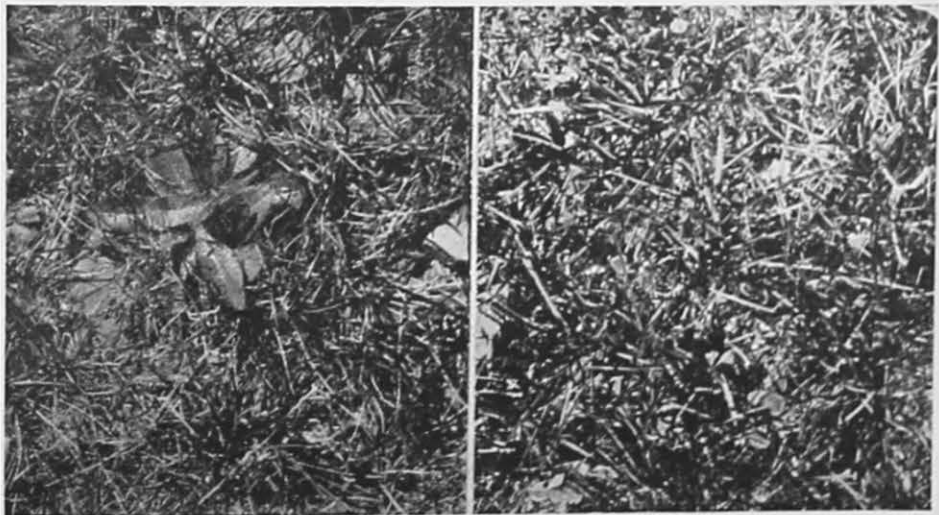


FIGURE 13. GOOD PASTURE SWARDS HOLD THE SOIL.

The thick thrifty sward at the left holds water and soil much better than does that at the right.

EFFECT OF PAST EROSION ON DEPTH OF SURFACE SOIL, ORGANIC-MATTER CONTENT, AND CROP YIELDS

To determine the cumulative effect of the management of the soil over the past three-quarters of a century, studies were made in 1942 and 1943 on several crops and soil types in this part of New York. In 1942, yields of potatoes were studied in Steuben County. The depth of surface soil (to the C horizon or layer) was determined, and plots were harvested at random. Every effort was made to take yields only where cultivation, fertilization, and everything but previous erosion, were the same. Yields were obtained again in 1943 as near the same spots as possible. The yields and depths of soil are given in table 12.

TABLE 12. EFFECT OF PREVIOUS EROSION ON YIELDS OF POTATOES IN STEUBEN COUNTY

| Average depth to C horizon | Past erosion | Slope of land | Average yield of potatoes* | |
|----------------------------|-----------------|-----------------|----------------------------|------------------------|
| | | | 1942 | 1943 |
| <i>Inches</i> | | <i>Per cent</i> | <i>Bushel per acre</i> | <i>Bushel per acre</i> |
| 40 | Some deposition | 1 | 517 | 353 |
| 22 | | Moderate) | 9 | 441 |
| 18 | Severe | 7-8 | 413 | 251 |
| 14 | | 9-12 | 347 | 187 |

*Average of 5 plots.

The first plot was at the base of a short slope. The washing of soil from the slope and its deposition undoubtedly account for the unusual depth of 40 inches. In both 1942 and 1943 potato yields were higher on the deeper soils. The reason is that the deeper soil constitutes a larger root zone, and holds more moisture and plant nutrients, and delivers them to the crop when needed. The high yields in 1942 resulted from heavy fertilization, excellent management, and a favorable season. These conditions were less favorable in 1943, but fairly good yields were obtained. Nevertheless, the yields were lower on the plots where most erosion, as measured in thinner soil remaining, had taken place in years past. The deeper reservoir for holding water, of course, is most important in dry seasons or in seasons when long dry periods occur in July, August, and September.

In 1943, yields of oats, beans, silage corn, and potatoes were taken in four counties on four additional soils. The data are given in table 13.

On the soils in these counties, as in Steuben, the yield was higher on the deeper soil, or the one that had undergone less erosion in the past. In the one comparison between contour and up- and downhill rows (Mardin soil, Steuben County), the yield of potatoes was one-sixth, or 17 per cent, greater on the contour than in up- and downhill rows.

In every comparison the yield was higher on the deeper soil, and also the deeper soil had a higher percentage of organic matter. There are two reasons for the higher organic-matter content:

1. Organic matter naturally accumulated in the top 8 or 10 inches of the virgin soil. As topsoil is lost the plow brings up soil material that is deficient in organic matter, and mixes it with what remains of the eroded topsoil. The latter, therefore, is diluted and has a lower organic content.

TABLE 13. EFFECT OF PREVIOUS EROSION ON CROP YIELDS AND ON ORGANIC-MATTER CONTENT OF SEVERAL SOIL TYPES, 1943

| County | Crop | Soil type | Slope | Direction of rows | Depth of soil | Organic matter | Yield per acre |
|-------------|-------------|------------------------|-----------------|-----------------------------|---------------|-----------------|----------------|
| | | | <i>Per cent</i> | | <i>Inches</i> | <i>Per cent</i> | <i>Bushels</i> |
| Allegheny.. | Oats | { Erie silt loam } | 12 | { Contour Contour | 6 9 | 2.5 3.6 | 23 38 |
| Wyoming. | Beans | { Darien silt loam } | 15 | { Contour Contour | 5 13 | 2.5 4.3 | 5 14 |
| Steuben .. | Potatoes | { Mardin silt loam } | { 6 5 | Up- and downhill Contour | 13 11 | 2.9 3.3 | 163 191 |
| Chenango. | Silage corn | { Canfield silt loam } | { 12 10 | Contour Contour | 6 13 | 4.3 5.5 | (7.2)* 11.8 |

*Tons.

2. Some organic material is dissolved and thus lost from the soil, and some bits of organic matter on the surface are floated off in surface runoff and thus lost from the soil. Even light rains that cause runoff may carry away dry organic matter from the surface of the soil.

Oat yields were one-half greater on 9 inches than on 6 inches of Erie surface soil above the compact, impervious layer. Beans made a poor yield (5 bushels) on a depth of 5 inches of Darien, a heavy soil with a compact, slow-draining subsoil, but almost three times the yield on 13 inches of topsoil.

The corn on Canfield silt loam in Chenango County produced nearly two-thirds more silage on 13 inches than on 6 inches of surface soil.

It appears, therefore, that loss of surface soil by erosion over the period of farming has materially reduced the ability of the soil to produce crops except as manures and fertilizers are supplied liberally and as moisture is successfully retained. In time these additions will improve the productive capacity of eroded soils, but it is costly on deep soils, and slow, if not uneconomic, on the soils that originally had the compact layer about 8 inches below the surface.

EFFECT OF PASTURING WOODLOTS

A study was made of a pastured and of an ungrazed woodlot. The difference in appearance under these two conditions is shown in figure 14.

Young seedlings are lacking for ground cover and for renewal of the forest, as shown in the pastured area on the left in this figure; whereas the undergrowth in the area on the right, which is fenced to keep out the stock, is thrifty. Such growth tends to hold rain and snow. The ground surface is protected by leaves and twigs, which delay runoff by absorbing water directly, and by improving the rapidity of intake of water by the soil, in comparison with pastured woods or cropped land. Undisturbed, protected woodlots hold back rain and snow water until the water falling on less absorptive soils has gone down into the valleys. Also, less freezing takes place under a good cover of leaves, particularly when snowfall is ample. The snow is held in the undergrowth of an ungrazed woodlot, and the dense shade, as from spruce, pine, and hemlock, and reduced air movement delay thawing in the spring. This delay enables the soil to take up more of the water for later use as ground water



FIGURE 14. GRAZED AND UNGRAZED WOODLOT

Note the small amount of surface litter in the grazed area on the left and the fine undergrowth of seedlings on the right. These latter protect the soil and hold both snow and rainfall.

for wells, springs, and streams. Also, this water is delayed in reaching the larger valleys, thereby reducing the crests of spring floods.

VINEYARD EXPERIMENTS AT HAMMONDSPORT*

The commercial vineyards of the Finger Lakes area are mainly on the long slopes adjacent to the larger lakes. The long frost-free season, the temperate climate, the comparative freedom from disease, and the favorable soil combine to produce large yields of table and wine grapes of high quality. Commercial grape production began about 85 years ago, the first winery being established in 1860.

The rainfall during the growing season in this area consists of thunderstorms of high intensity and an occasional prolonged heavy rain. Alternated with these rains are periods of drought. Holding sufficient water on these slopes, therefore, is a major problem of grape production.

EROSION IN THE VINEYARDS

The vines originally were planted without much regard to slope. Rows up- and downhill or angling downhill are the rule, although a few of the vineyards were planted on the contour. Clean cultivation has been the common practice. Serious sheet and gully erosion, especially on the steeper slopes, has caused decreases in yield, and has contributed to the abandonment of many vineyards, which were ideally located with respect to protection from frost by the lake.

*The experiments for the control of erosion in vineyards are under the immediate direction of S. E. Collison, Soil Conservation Service, Research, working in cooperation with Professor Richard Wellington of the New York State Agricultural Experiment Station at Geneva.

EXPERIMENTS IN THE CONTROL OF EROSION IN VINEYARDS

The following lines of work were undertaken:

1. Measurement of losses of water and soil.
2. Use of cover crops.
3. Establishing new vines on badly eroded land.

MEASUREMENT OF LOSS OF WATER AND SOIL

In 1935, four plots, 48 by 225 feet each, were selected for measurement of losses of water and soil. The grapes are of the Elvira variety. On one plot the rows run up- and downhill, and on the other three the rows are essentially on the contour. The slope is 24 per cent. Although losses have not been large, the up- and downhill rows lost about three times as much water and 55 times as much soil as did the contour rows. In July 1939 one-half of a rain of 3.62 inches fell in 30 minutes. The up- and downhill rows lost one-third inch of water and 2793 pounds of soil an acre, while the contour rows lost practically no water or soil. In other words, this soil, with grapevines on the contour, takes up the water and, therefore, little runoff and erosion occur (figure 15). Past erosion has been so severe that less than one-third of the topsoil now consists of material fine enough to hold water and plant nutrients. Continued loss may lead to abandonment.

In general the yields of grapes indicate a beneficial effect from the water retained by the contour rows.

COVER CROPS

In 1935 on one of the contour plots, every fourth "middle" was seeded to Ladino clover, rotated from year to year; the other three middles

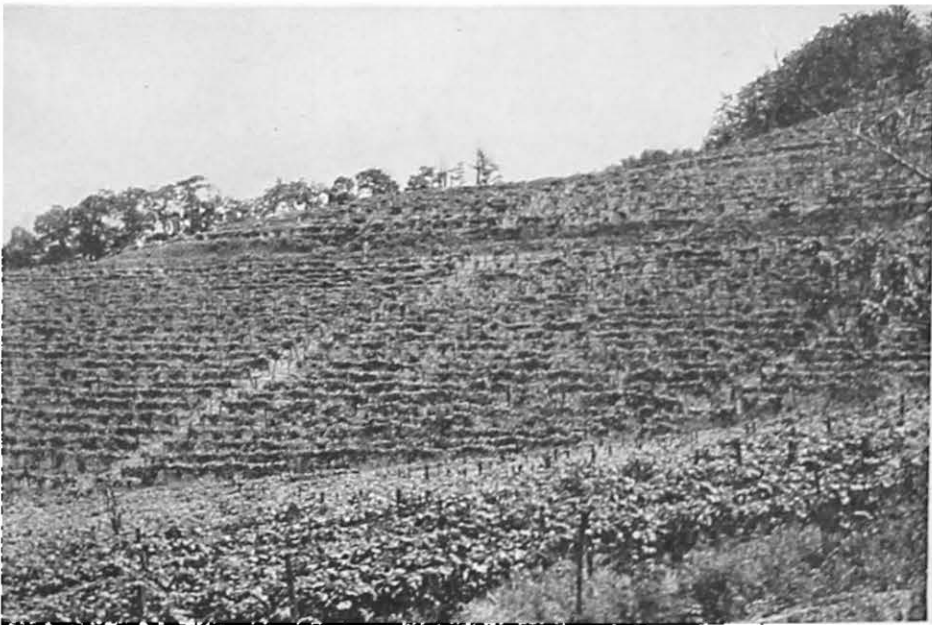


FIGURE 15. GRAPES ON THE CONTOUR

The soil under these contour-planted grapes southeast of Hammondsport did not suffer serious damage from 8 inches of rain in 24 hours. The slope is 31 per cent. Under similar conditions soil washing was severe in grapes planted up- and downhill.

were clean-cultivated. The remaining contour plot was seeded solid to Ladino clover. After 1937 the clover was mowed to reduce competition with the grapes. The application of 200 pounds an acre of nitrate of soda was increased to 300 pounds in 1939. The clover has reduced yields of grapes; competition for moisture appears to be the cause. The cover crop was kept short by frequent mowing in 1939. Yields then were essentially the same as on the clean-tilled contour plot.

ESTABLISHING NEW VINES ON BADLY ERODED LAND

In 1937 old Concord vines were removed from a badly eroded area of Groton soil with a slope of 35 to 45 per cent. Ten tons of manure and 600 pounds of superphosphate an acre were applied, and the land prepared. Part of the area was terraced at a cost of \$25 an acre. The vertical distance between terraces was 5 feet, and the average distance between the terrace ridges on which the vines were planted was 8 feet. On clean-cultivated land, 10 per cent of the Delaware vines on their own roots survived. Of the clean-cultivated Delaware vines grafted onto vigorous rootstocks, 63 per cent survived, and when mulched 86 per cent survived.

At the Arnot Station the loss of water by evaporation in 61 days in 1939 with 5.02 inches of rainfall was 54 per cent from fallow, 49 per cent from soil two-thirds of which was covered with stones, and 29 per cent from a straw mulch (6 tons an acre). A comparison of straw-mulched soil with fallow soil is given in table 14.

TABLE 14. LOSSES OF WATER AND SOIL FROM MULCHED AND FALLOWED SOIL, ARNOT STATION (AVERAGE FOR 1940, 1941, AND 1942)*

| Plot | Treatment | Rainfall† | Loss | |
|----------|-----------|-----------------------|-----------------------|--------------------------------|
| | | | Water | Soil |
| B10..... | Fallowed | <i>Inches</i> 22.4 | <i>Inches</i> 1.93 | <i>Pounds per acre</i> 9132 |
| B15..... | Mulched‡ | 22.4 | 0.16 | Trace |

*Bath flaggy silt loam.

†May through October.

‡Six tons of oat straw an acre on August 1, 1939, and the same quantity on June 29, 1942.

Severe injury from drought occurred in 1939 on the clean-cultivated area. On the mulched area the appearance of the vines was favorable, and the soil contained more moisture than did the clean-tilled land. More than twice as much growth on the basis of weight of prunings was made on the mulched area. The first fruit was picked in 1940, 100 mulched vines yielding 220 pounds, as compared with 122 pounds from 100 clean-tilled vines.

A comparison on the farm of Don Wickham near Hector was made in 1939; approximately 12 tons of straw an acre was applied in February. As an average for the seasons 1939 and 1940, the mulched vines produced 7125 pounds of fruit an acre, and the clean-cultivated, 5325 pounds, an increase of 1800 pounds for 12 tons of straw mulch. In 1941 there was little difference in yield, and some evidence of late growth and winter injury caused by an oversupply of nitrogen was noted.

This progress report indicates the definite need for additional research on the problem of holding the soil for future grape production.