Rotations in Conservation

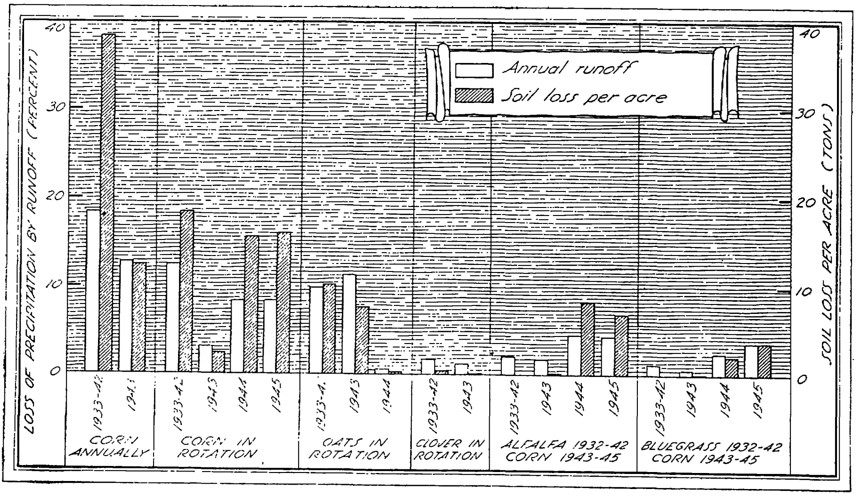
by R. E. UHLAND

GOOD CROP rotations provide for systematic cropping of land in a way that will maintain or improve soil fertility, yields, and the nutrient value of the crops. The type of rotation that should be used on any given piece of farm land depends on the characteristics of the land. If the land is very steep, only sod crops can protect it against serious erosion. If it is gently rolling, rotations that provide a sod cover 1 or 2 years out of every 3 to 5 will keep it from deteriorating. Some level lands can safely be tilled almost every year. Any cropping system, to be fully effective, should be supplemented with conservation practices such as contouring, terracing, application of needed plant foods, soil amendments, return of crop residues and manures, and strip cropping, according to the needs of the particular field or farm.

A glance back at some recent experiences will show the importance of rotations in our future farming.

Although our land has suffered a great deal because of erosion and deterioration, it still possesses enormous unexhausted soil productivity, as demonstrated by the 30-percent increase in wartime food production. That production was something to be proud of, but it involved a speed-up in exploitation of our soil resources, which was not counterbalanced by soil-conserving practices. Many farmers, in fact, dropped legumes from their rotations during the emergency, with the result that much soil organic matter and nitrogen were lost.

The tremendous part that unexploited soil productivity played in supplying food during the war years 1942 and 1943 is illustrated by the relative production during those years of the lands that were more recently brought into use for crop production. In those 2 years the North Central Crop Reporting Division, which includes Ohio, Indiana,



Here is shown the amount of runoff and soil loss from plots of 9-percent slope under various cropping systems on Marshall silt loam at Clarinda, Iowa, from 1933 to 1945. The average rainfall from 1932 to 1942 was 28.33 inches; 31.1 inches in 1943; 39.24 in 1944; and 34.78 in 1945. The corn plots were listed on the contour in 1943 and surface planted up and down the slope in the other years.

Illinois, Minnesota, Nebraska, Kansas, North Dakota, and South Dakota, produced these large percentages of the Nation's total of principal food and feed crops: Corn, 76.7; soybeans harvested for grain, 92.8; wheat, 59.5; oats, 82.3; tame hay, 49.9; alfalfa, 37.8; cattle and calves, 54.1; sheep and lambs, 35.9; and hogs, 74.7.

In 1935–39, intertilled crops were grown on 46 percent of all the land used for crops in the five Corn Belt States—Ohio, Indiana, Illinois, Iowa, and Missouri. In 1943–44, the corresponding percentage was 52.1. In Iowa, the percentages of all cropland on which intertilled crops were grown in the two periods were 45.7 and 52.5; in Illinois, they were 50 and 56.9; in Ohio, 38.2 and 45.5. With such proportions of all cropland under tillage in 1943–44, the best possible sequence of crops would not have prevented excessive exploitation of soil resources.

A productivity balance—that is, the net result of the processes contributing to soil productivity and those tending to exhaust it—has been computed for the soils of Ohio farm lands for each of the years from 1929 to 1945 according to a system devised at the Ohio Agricultural Experiment Station. The results indicate that deterioration of the soils slackened during the first decade of that period; the productivity balance changed from a 0.65-percent loss in 1929 to a 0.5-percent loss in 1939. Under the pressure of war, the trend was reversed; the loss increased from 0.61 percent in 1942 to 0.78 in 1945.

If the same system of measuring the soil-productivity balance were applied for all Iowa and Illinois, the calculated wartime losses would be greater than those for Ohio; in those States, much larger percentages of cropland were used to grow intertilled crops and the practice of growing such crops year after year on the same land was much more common. These figures point to an inescapable conclusion of the highest importance to every farmer and every other citizen: During the next few years agriculture in the Corn Belt and in the entire United States must be directed toward attaining a positive balance in soil productivity through appropriate crop rotations and supporting practices.

Crop Rotations Control Runoff and Erosion

Experiments conducted by a number of State agricultural experiment stations and the Soil Conservation Service have shown that type of crop and type of cultivation have a marked influence upon runoff and erosion. I give a few examples.

At Bethany, Mo., a Shelby loam area cropped annually to corn for 10 years lost 27.2 percent of the rainfall as runoff and, on an average, lost annually 50.9 tons of soil per acre, equivalent to more than one-third inch. Adjacent land that was cropped to a 3-year rotation of corn-wheat-hay lost only 16.5 percent of the rainfall as runoff and lost only 7.51 tons of soil per acre annually. Continuous covers of alfalfa and bluegrass permitted only 6.7 and 8.1 percent runoff, respectively, with only a trace (0.15 ton an acre) of soil loss.

At Temple, Tex., a plot of Houston clay soil with a 2-percent slope cropped annually to corn for 11 years lost 8.8 percent of the precipitation and 22.72 tons of soil an acre a year. Adjacent land in Bermuda grass lost only a trace of water and soil. When oats followed the corn, 13.4 percent of the precipitation ran off and annual soil loss per acre averaged 2.06 tons.

The runoff and erosion from a 7.7-percent slope of virgin Stephensonville fine sandy loam cropped to a rotation of cotton-wheat-sweetclover at Guthrie, Okla., were compared with those from adjacent plots where cotton was grown annually. The water losses were 9.29 percent and 11.35 percent, respectively. The annual soil losses from the land in cotton averaged 4.4 times as great as those from the land in rotation. Percentages of water lost from areas in cotton, wheat, and sweetclover averaged 10.07, 11.55, and 6.25; annual soil losses averaged 9.04, 1.69, and 0.52 tons an acre. Soil loss from cotton in rotation was only a little more than half that from annual cotton. Here again the results clearly show the value of wheat and legumes in a rotation in retarding loss of soil.

Near Zanesville, Ohio, in 1934–42, the runoff from land in a 4-year rotation was only half that from land cropped continuously to corn, and the soil loss was less than one-seventh as great.

Similar results were obtained on Marshall silt loam near Clarinda,

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Iowa. In the 10 years 1933–42, land cropped annually to corn lost 2.3 times as much of the precipitation and 5.32 times as much soil as land in a 3-year rotation of corn-oats-clover. Low runoff and only a trace of soil loss were recorded for plots in alfalfa and bluegrass. A marked cumulative influence of these two crops in reducing erosion became evident when the land was plowed and planted to corn.

Investigations on many farms in different sections of the Corn Belt have yielded evidence as to how type of cropping and farm cultural practices affect depth of topsoil and, consequently, yield of corn. Loss of topsoil through erosion from fields under different cropping systems and from different locations within a field was clearly reflected in crop yields. Yields of corn in relation to depth of topsoil for 18 fields near Fowler, Ind., in 1940 were found to be:

Depth of topsoil (inches)	*Corn yield per acre (bushels)*	*Depth of topsoil (inches)*	*Corn yield per acre (bushels)*
0	19.8	7–8	53.1
1–2	30.0	9–10	56.8
3–4	39.2	11–12	62.4
5–6	47.0	12+	69.5

You will note that where practically all the topsoil was gone the yield of corn to the acre averaged much less than half of what it was where 7 to 8 inches of topsoil remained and less than a third of what it was where the topsoil was 11 to 12 inches deep. Similar results were obtained in other studies near Fowler, at Coshocton, Ohio, at Bethany, Mo., and at Shenandoah and Greenfield, Iowa.

Soil Aggregation Improved by Rotating Crops

Much of the benefit from growing sod crops is due to the influence they have upon aggregation, or the binding together, of soil particles. A high degree of aggregation permits rapid movement of water and air within the soil and consequently prevents excessive runoff.

Marshall silt loam plots on which alfalfa and bluegrass had been grown were found to have 50 and 58 percent greater soil aggregation, respectively, than plots on which corn had been grown annually. The improvement in aggregation on the plots formerly in alfalfa and bluegrass was still evident when these plots had been cropped to corn for 3 years. The losses of water and soil from the plots for the 3 years they were in corn, 1943–45, were markedly less than those from plots where a single crop of corn followed one of clover. In other words, land should be kept in a hay crop two or more years at a time in order to improve aggregation and stabilize the soil.

To find what effects different cropping systems had had on the stability of aggregates in soil at Bethany, Mo., we made counts of the drops of water, falling 30 centimeters, required to disperse an aggregate about the size of a BB shot and wash it through a 20-mesh screen. Tests were made on 180 aggregates taken from the surface inch of soil on each plot. Aggregates of soil on which corn had been grown and of soil that had lain fallow were collected in early spring when oats had been seeded and had grown to a height of about an inch. The results:

Cropping system	*Average number of drops required to disperse aggregate*	*Cropping system*	*Average number of drops required to disperse aggregate*
Corn annually	6.2	Alfalfa 13 years	40.2
First-year meadow	37.7	Bluegrass 13 years	31.2
Corn after meadow	10.1	Clean fallow 13 years	7.5
Second-year meadow	41.2		

All over the country one can observe the superior physical condition of soils under sods. Where sod has been turned under for corn, more rapid infiltration and less runoff and erosion occur. Also, microbial activity and aeration are greater than where corn has been grown annually.

Rotations Increase Soil Organic Matter and Yields

On nine experimental plots having an 8-percent slope at Bethany, the organic-matter content of the soil at plow depth (the top 7 inches) was 3.25 percent in 1930. For the next 13 years the plots were variously cropped or permitted to lie fallow, and plots 6 and 7 were treated with lime and phosphate. In 1943 a second test was made to determine soil organic-matter content. The result was:

Plot No.	*Cropping system*	*Organic matter Percent*
2	Corn annually	2.23
3	Rotation corn-wheat-clover	3.23
4	Rotation corn-wheat-clover	3.23
5	Rotation corn-wheat-clover	3.15
6	Rotation corn-wheat-clover	3.38
7	Alfalfa, continuous	3.93
8	Bluegrass, continuous	3.61
9	Topsoil, clean fallow	1.93
10	Subsoil, clean fallow	1.41

The depletion of nitrogen in soils that had been farmed poorly for 50 to 75 years was disclosed in tests by the Ohio Agricultural Experiment Station of seven such soils and comparable virgin soils of adjacent areas. The nitrogen content of the top 7 inches of these cropped Ohio soils had been reduced by from 17 to 48 percent.

After 60 years of cropping to corn and oats the soil organic matter at plow depth of a Shelby loam area in northern Harrison County, Mo., averaged 1.83 percent. On an adjacent area that had remained in grass during the period, the corresponding percentage was 5.91. Similar Harrison County land cropped to a good rotation for nearly 60 years still retained 4.11 percent organic matter in the plow depth. Land under

This table shows the average annual yields of individual crops and of digestible nutrients produced under different cropping systems in tests made on Wooster silt loam by the Ohio Agricultural Experiment Station in 1921–35. It also shows the nitrogen content of the cropped soil at the end of the test period.

Item	Corn annually	2-year rotation	3-year rotation	4-year rotation	5-year rotation
Corn....bushels..	27.0	64.0	77.2	70.6	82.1
Oats....do....	....	....	....	....	62.9
Wheat....do....	....	32.4	38.3	38.4	....
Alfalfa:					
First-year....tons....	....	....	2.74	3.17	2.63
Second-year....do....	....	....	....	4.10	3.59
Third-year....do....	....	....	....	....	3.92
Total digestible proteins [1]...pounds..	108	237	382	520	533
Total digestible nutrients [1]....do....	1,215	2,250	2,710	3,092	3,055
Total nitrogen....do....	1,425	2,075	2,263	2,450	2,487

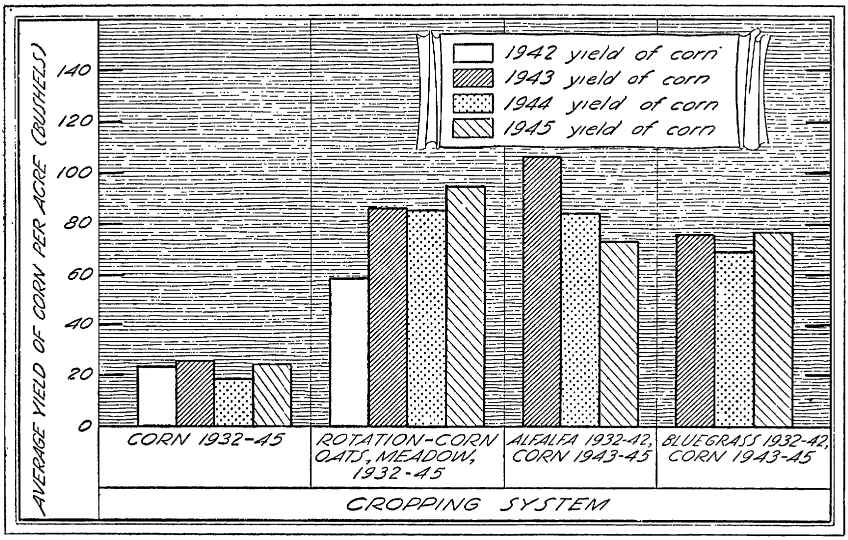
[1] Calculated on the basis of harvested grain and hay.

rotation cropping during this 60-year period lost about 30 percent of its original supply of organic matter; without rotation, the loss averaged 69 percent, or 2.3 times as much.

Crop rotations with varying proportions of corn were tested on Wooster silt loam by the Ohio station in 1921–35. Rotations of 4 and 5 years with only one crop of corn each produced larger amounts of digestible proteins and digestible nutrients annually than shorter rotations or continual cropping to corn. They produced five times as great an amount of digestible protein and twice as great an amount of digestible nutrients as continuous cropping to corn. Where a 5-year rotation had been practiced, the nitrogen in the plow depth of soil was 2,487 pounds an acre, compared with 1,425 pounds where corn had been grown annually.

Corn yields on Marshall silt loam at Clarinda, Iowa, were found to be affected markedly by previous cropping. For the 3 years 1943–45, plots cropped to a 3-year rotation of corn-oats-meadow yielded, on an average, 88.6 bushels an acre, or 3.87 times as much as nearby plots that had been cropped to corn annually since 1932. The lower yield on the annual-corn plots was attributed to damage by the northern rootworm, nitrogen deficiency, and the poor physical condition of the soil. Great damage was done by the northern rootworm where two or more crops of corn were grown in succession. Such damage was rather common in southwestern Iowa.

Similar insect injury to crops is associated with continuous cropping in many sections. High yields of corn are common after crops like alfalfa and bluegrass, which have a fine network of roots that permeate the soil. Each year, many of the roots die and supply organic material to the soil. The action of roots in binding soil particles together, plus alternation of



The average annual yields of corn on variously cropped plots of Marshall silt loam at Clarinda, Iowa, from 1942 to 1945.

wetting and drying and of freezing and thawing, brings about a granular condition characteristic of soil under sod. When land in grass or meadow is turned for corn, the rotting of the roots and stubble makes much plant food available for the corn.

On the Fry farm, near Wooster, Ohio, injury from drought to corn that was grown in a rotation was much less where corn occupied the land only a small part of the time than where two or more crops of corn were grown in sequence. Where a 5-year rotation included 3 years of alfalfa and 1 year each of corn and wheat, corn yielded 40 bushels an acre in the drought year 1944, in contrast with only 15 bushels where the rotation included 3 years of corn. Where the 5-year rotation was supported by applying manure or leaving crop residues, the yield in 1944 was 45 bushels an acre. The corn yield for the 3-year rotation of corn–wheat–sweetclover was markedly lower in both 1943 and 1944 than that for the longer rotations.

Rotations for Improving Eroded Land

Much of the cropland in different sections of the United States has lost a large part of its topsoil. The productive capacity of severely eroded lands can be increased, although it cannot be fully restored. The Ohio experiment station initiated a study in 1937 to determine the relative crop production of topsoil and subsoil. Measurements were made of yields of hay in 1940 and corn in 1941 on topsoil and subsoil under differ-

A crop rotation of corn-wheat-alfalfa-alfalfa, plus lime, fertilizer, and manure, resulted in best yields of hay and corn in tests begun at the Ohio experiment station in 1937. Yields from subsoil were less than those from topsoil.

Soil management system,[1] including rotation	Hay yield per acre, 1940		Corn yield per acre, 1941	
	Topsoil	Subsoil	Topsoil	Subsoil
	Tons	*Tons*	*Bushels*	*Bushels*
C-O-W-Rdcl	2.8	1.4	67	32
C-O-W-Rdcl, L	3.1	1.3	64	28
C-O-W-Rdcl, L+F	3.1	2.2	83	44
C-O-W-Rdcl, L+F+M	3.6	2.7	108	64
C-W-A-A, L+F	3.7	3.4	121	76
C-W-A-A, L+F+M	4.1	3.6	125	86

[1] C=corn, O=oats, W=wheat, Rdcl=red clover, L=lime, F=fertilizer, M=manure, A=alfalfa.

ent systems of cropping and management. Higher yields of hay and corn on both topsoil and subsoil were obtained through combined soil treatments. Yields on subsoil remained substantially lower than those on topsoil, a fact that emphasizes the desirability of initiating good rotations and whatever other conservation practices are needed before serious erosion or soil deterioration takes place.

In preliminary studies at McCredie, Mo., rotations including deep-rooting legumes proved effective in deepening the feeding zone for crops in Putnam silt loam. Placing lime and fertilizer deep in this soil facilitated deepening of the root zone. When lime and fertilizer had been placed at a depth of 9 to 18 inches in the shattered claypan soil, sweetclover roots penetrated to a depth of 20 inches, compared with 6 or 8 inches where only the topsoil was treated. Corn following sweetclover on this specially treated soil in 1945 yielded 6 to 9 bushels more to the acre than corn following sweetclover on adjacent plots where subsurface treatment had not been given.

The part played by crop rotations and soil management in rebuilding eroded soils is further illustrated by the results of an experiment carried out at Bethany, Mo., in 1932–42 to find how rapidly the organic-matter content of exposed subsoil of Shelby loam and crop yields from this soil might be increased. Seven plots were subjected to four cropping systems, with and without soil treatments. The topsoil of the experimental area had been eroded to about half its original depth. Except on plot 1, the remaining topsoil was removed artificially. Plots 3–7 were treated with lime and with superphosphate, which was applied on oats at the rate of 200 pounds per acre. Manure was applied on plot 6 before corn, at the rate of 8 tons per acre. Rainfall during the experimental period was scanty. In 1942 corn was grown on all the plots, to find how corn yields might be affected by past cropping and management. The cropping system and the 1942 corn yields were as follows:

Plot No.	*Cropping system*	*Yield of corn per acre (bushels)*
1	Corn-oats-red clover and timothy-timothy	43.0
2	Corn-oats-red clover and timothy-timothy	20.5
3	Corn-oats-red clover and timothy-timothy	34.6
4	Corn-oats-red clover and timothy	32.2
5	Corn-oats-sweetclover (sweetclover turned under)	44.0
6	Corn-oats-sweetclover (sweetclover turned under)	64.6
7	Grass-legume mixture, not harvested	44.2

The 1942 corn yield of plot 2, untreated subsoil, was 48 percent of that of plot 1, untreated topsoil. Plot 3, exposed subsoil that was limed and fertilized, yielded 80 percent as much corn as the untreated topsoil. Plot 5, with a 3-year rotation including sweetclover which was turned under in the spring before corn was planted, yielded 102 percent as much corn as plot 1. (Fields with topsoil comparable to that of plot 1 that were treated with lime and superphosphate yielded about 80 bushels of corn an acre, or almost twice as much as plot 1.) Where manure was applied before sweetclover grown on exposed subsoil was turned under for corn, the corn yield was 150 percent of the yield from the comparable plot where manure was not applied. On plot 7, which was limed and fertilized and seeded to a grass-legume mixture that occupied the land for 10 years, the 1942 corn yield was 102 percent of the yield of untreated topsoil and 215 percent of that of untreated subsoil.

In this Missouri experiment runoff and soil loss averaged markedly lower for the higher-yielding subsoil plots. For example, for plot 2 the water loss was 1.63 times as great as for plot 3 and the soil loss was 2.3 times as great. These results emphasize the desirability of using needed soil amendments to rebuild eroded soils. The highest gains in soil organic matter were recorded for plot 6, on which sweetclover was turned under and manure was applied, and plot 7, where a good grass-legume cover was maintained for 10 years without being harvested.

On many eroded areas, crop rotations cannot satisfactorily be used until large quantities of lime have been applied, along with needed mineral fertilizers. Figures compiled in 1945 by C. E. Carter, of the Production and Marketing Administration, indicate that cropland in the United States needs 36,618,000 tons of limestone a year and pasture land needs 14,762,000 tons. In the North Central States alone, the limestone needed annually for cropland and pasture land together was estimated at more than 25 million tons.

A farmer who grows only a single crop, such as corn, cotton, or wheat, not only exposes his soil to serious erosion and robs it of its stored plant nutrients but fails to provide steady employment for himself and his help throughout the year. A good rotation usually provides for cash crops, feed crops, and pasture. For this reason and because it improves the quantity and quality of crop yields, a good rotation makes possible the fullest and best use, all year, not only of soil, livestock, and equipment but also of labor, one of the largest items of cost in producing crops. Well-planned crop rotations, supported by other soil conservation practices and supplemented by the growing of livestock of the types that will best utilize the feed crops, provide steady employment and insure a more dependable farm income.

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FOR FURTHER READING

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