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Cropping Systems and Soil Fertility

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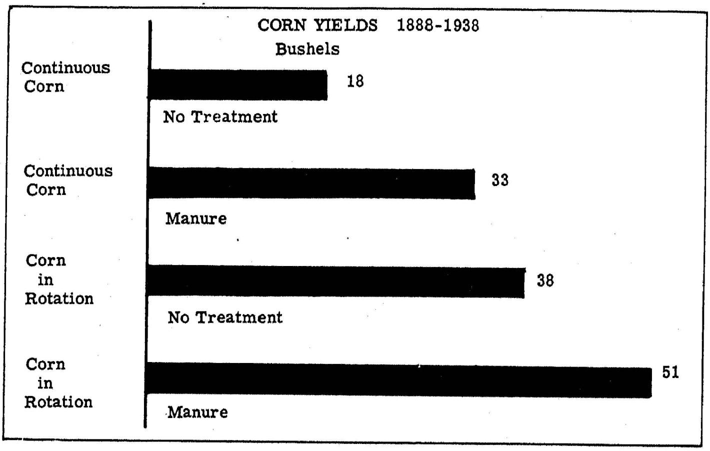

The cropping system and the fertility of the soil must both be considered in managing soils for high production.

Single crops grown continuously on the same land or different crops in a haphazard sequence present many problems of soil management not encountered when a regular rotation is followed. The kind of rotation to choose will depend on many and diverse factors. The fertility of the soil, the type of soil, its tilth, its slope, the climate, the insect pests, possible markets, the type of farming and the personal desires of the farmer must all be considered in making the choice. Foremost among these is the soil and its fertility.

Sanborn Field, at the Missouri Agricultural Experiment Station, now furnishes 50 years of results concerning the yields of crops, soil changes and the productive capacity of the soil as a

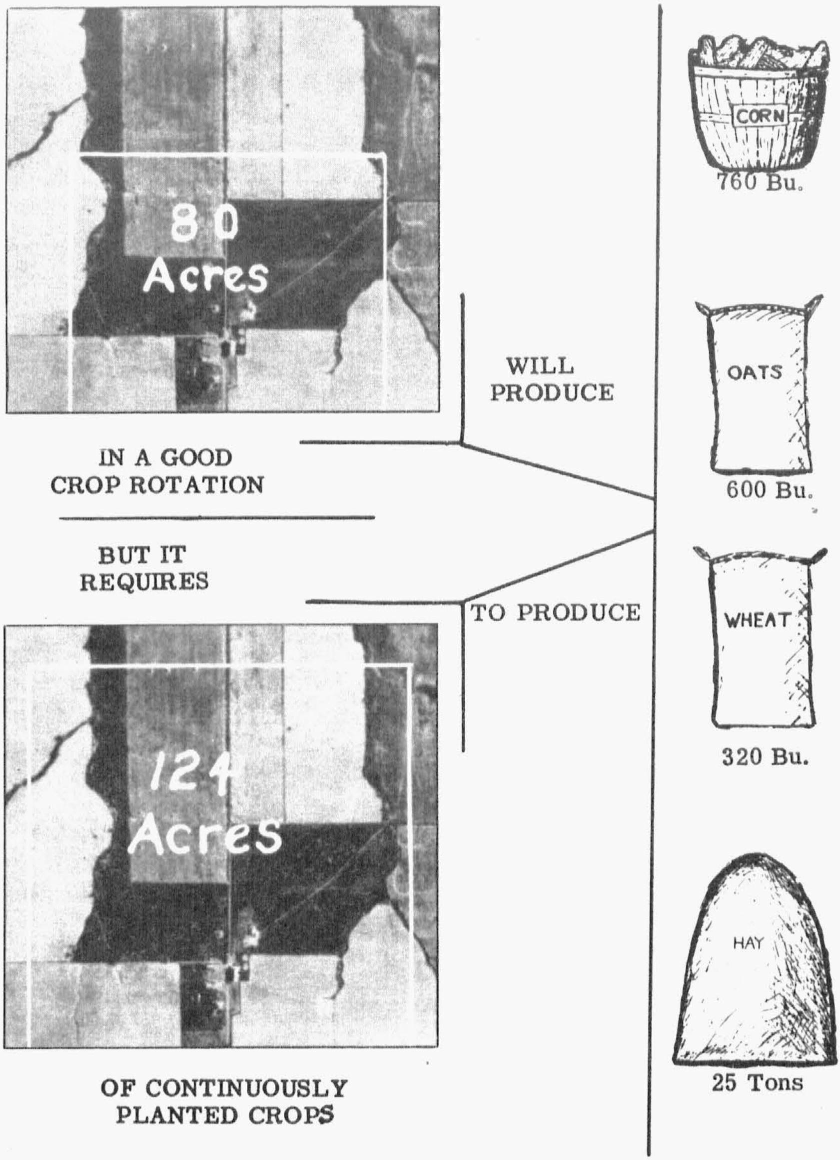

Fig. 1.—Under a good crop rotation 80 acres will produce as much grain and hay as 124 acres in continuously planted crops. (Total production in either case would be 760 bushels corn, 600 bushels oats, 320 bushels wheat, and 25 tons hay.)

result of different systems of cropping and soil management.* The records of this experiment field serve well as a means of measuring the influences of different cropping systems on soil fertility.

Rotations Aid in Maintaining Crop Yields

The results from Sanborn Field indicate that regular rotations are superior to continuous cropping and irregular cropping systems in maintaining crop yields. In specific cases the crop sequence may have a significant effect on crop yields. However, as long as a rotation is accompanied by good management so that the soil nitrogen and fertility are maintained, minor variations in cropping plan are of little importance.

Crop rotation alone cannot maintain the productivity of the soil. Where a supply of farm manure is available and properly utilized, particularly along with needed commercial fertilizers, the maintenance of a high fertility level of the soil under a good cropping system is comparatively simple. Where manures are not returned and crops are continually removed, provision must be made to grow green manure crops to replenish the soil's supply of organic matter, so important for high productivity. Likewise, when crops are sold, the mineral plant foods removed must be returned in the form of commercial fertilizers if a profitable level of crop production is to be maintained.

The most desirable rotation is one that produces the largest net value over a period of years while contributing to the conservation of the soil. In Missouri, corn has been the most universally grown crop and therefore most rotations have been centered around it. Since the soil fertility declines most rapidly under corn, the frequency with which corn is grown should be no greater than will permit the maintenance of the soil productivity.

When the crop yields in a rotation are compared with those in continuous cropping, the much larger yields in a rotation are immediately evident (Figure 2). The exhaustive effects by any one crop in the rotation are not so great as when the same crop is used continuously. If these exhaustive effects on soils are offset by applications of manure, then crop yields in continuous cropping do not fall so far below those in rotation. Though the yield of corn in rotation without soil treatment was significantly higher than of corn grown continuously, continuous wheat with manure was only three bushels below the yield of this crop

*The complete results from Sanborn Field for 50 years are reported in Missouri Agricultural Experiment Station Bulletin 458 (December, 1942).

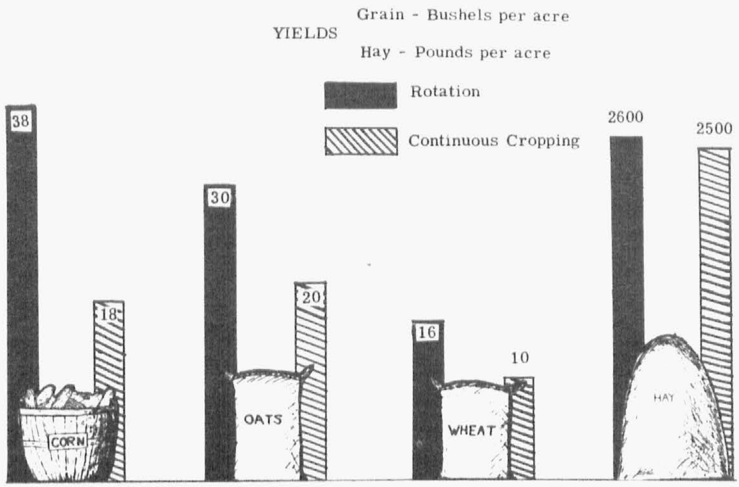

Fig. 2.—Yields of crops (average of 50 years) in six-year rotation and in continuous cropping with no manure or fertilizer applied.

grown in rotation without treatment. Viewed in terms of only a few rounds of the rotation, one might be led to believe that a rotation is as effective in maintaining crop yields as is an application of 6 tons of manure. However, it must be remembered that crop rotation alone does not replace the soil fertility removed in the crops (Figure 3).

Fig. 3.—Crop rotation increased the yield of corn.
Left—Corn continuously—33 bu. per acre. Right—Corn in rotation—51 bu. per acre.
(Average of 50 years; 6 tons manure annually.)

TABLE 1. AVERAGE YIELDS DURING 50 YEARS OF CROPS IN VARIOUS ROTATION AND CONTINUOUS CROPPING SYSTEMS

Cropping system	Corn		Oats		Wheat		Clover		Timothy		Average annual value of crops*	
	No treatment	Manure	No treatment	Manure	No treatment	Manure	No treatment	Manure	No treatment	Manure	No treatment	Manure
	bus.	bus.	bus.	bus.	bus.	bus.	lbs.	lbs.	lbs.	lbs.	$	$
Six year rotation	37.9	50.8	29.7	31.9	18.5	28.2	2059	4464	2500	4525	$12.00	$19.25
Four year rotation	36.6**	45.0	26.8**	37.2	21.6**	21.5	2216**	4000	---	---	15.47	20.36
Three year rotation	31.7	46.9	---	---	13.8	25.1	1656	4446	---	---	13.02	23.98
Continuous Corn	18.5	33.1	---	---	---	---	---	---	---	---	11.28	19.44
Continuous oats	---	---	20.1	33.0	---	---	---	---	---	---	7.75	13.75
Continuous wheat	---	---	---	---	10.3	18.8	---	---	---	---	9.32	17.28
Continuous timothy	---	---	---	---	---	---	---	---	2530‡	5097	7.59	15.29

* All straw and forage calculated in value of crops.
**Has been contaminated by lime dust from street.
‡ A poor quality of timothy because of much weeds.

There is little difference in yields in the rotations of different lengths as is evident from the yield figures given in Table 1.

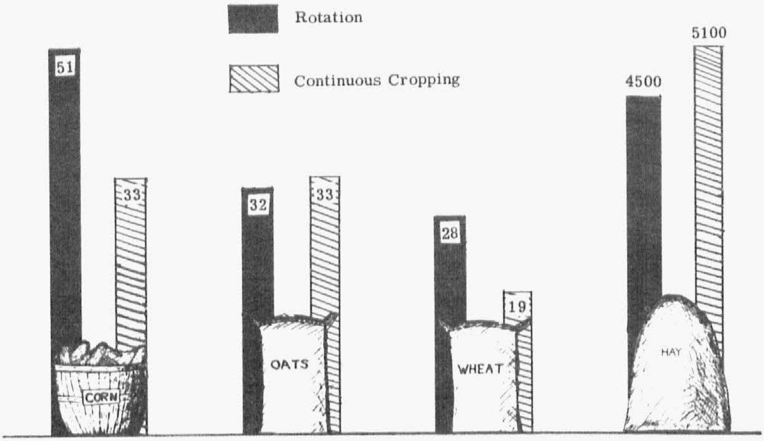

Fig. 4.—Yields of crops (average of 50 years) in six-year rotation and in continuous cropping with 6 tons of manure applied annually. Yields of grain are indicated in bushels per acre; yields of hay in pounds per acre.

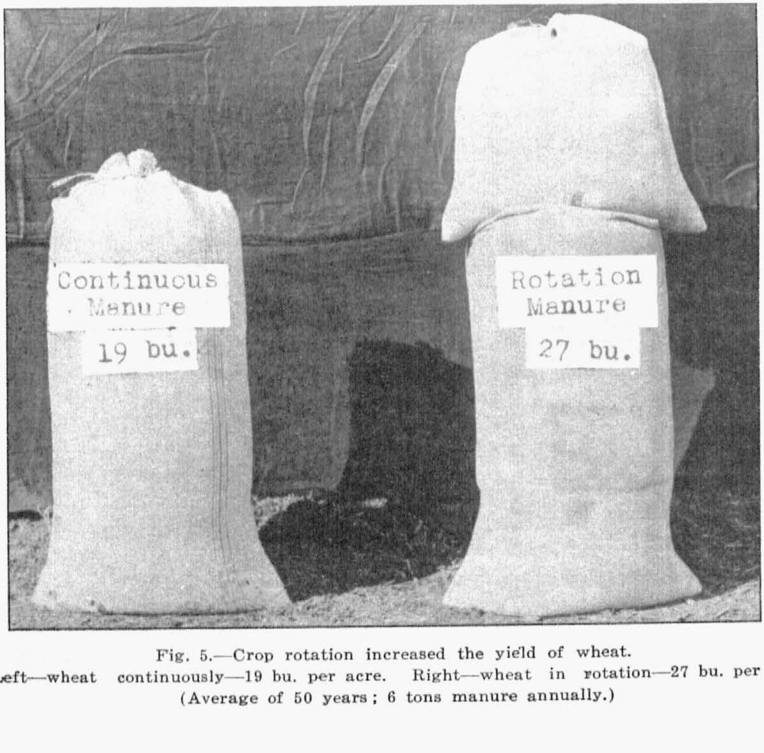

Fig. 5.—Crop rotation increased the yield of wheat.
Left—wheat continuously—19 bu. per acre. Right—wheat in rotation—27 bu. per acre.
(Average of 50 years; 6 tons manure annually.)

There is an indication that yields are higher as the rotation is longer, or as the corn occurs less frequently. However these small differences between rotations appear insignificant when compared to the increases brought about by soil treatments (Figures 4 and 5).

Although some of the continuous plots have given gross monetary returns comparable to those from the rotation plots, yet this measured production has been at the expense of future productivity of the soil. That these are the facts is evident from the trends shown in Figures 6 and 7.

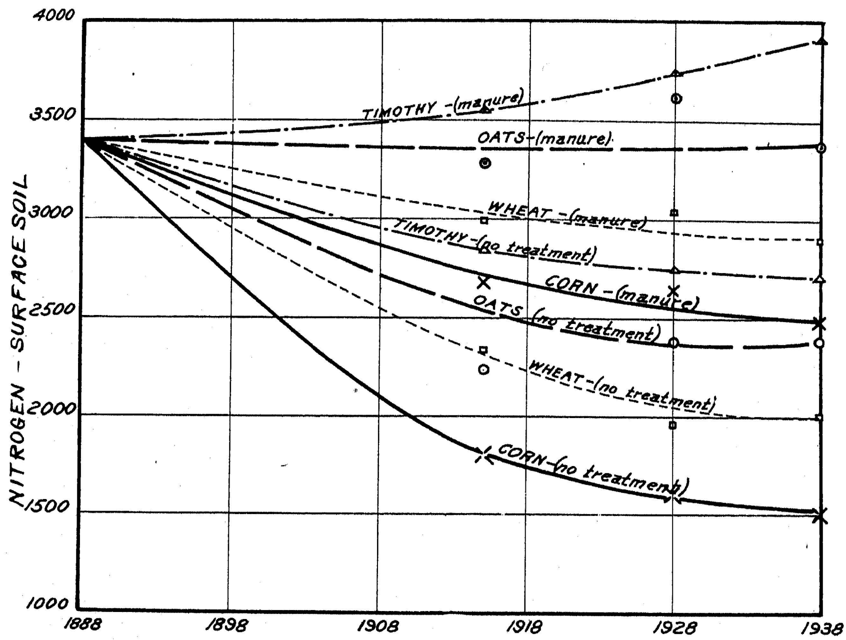

Fig. 6.—Changes in nitrogen content of surface soil from plots in continuous croppings both with and without manure. (The figure for the virgin soil is from roadway between plots and from adjacent open wooded area that has never been plowed and has been maintained in bluegrass.)

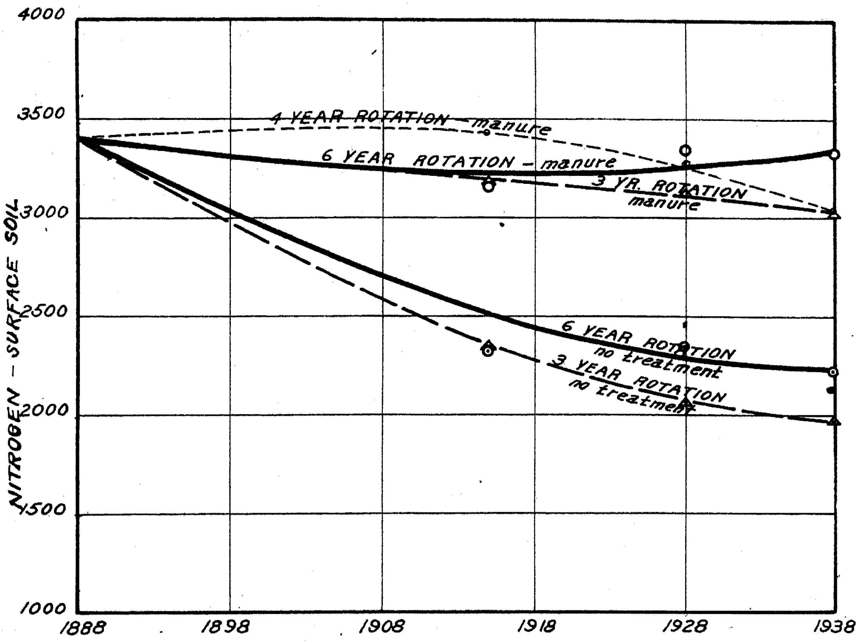

Fig. 7.—Changes in nitrogen content of surface soil from plots in rotation croppings both with and without manure.

Crop Rotations and Maintenance of the Nitrogen of the Soil

The efficiency of any system of cropping will depend not alone upon its capacity to produce an immediate profit, but on its ability to maintain the soil fertility and to guarantee a permanent soil productivity. Under Missouri conditions one of the better measures of soil productivity is the soil's content of nitrogen. Not only is nitrogen necessary for the balanced growth of all plants, but it serves as an index of soil organic matter which in turn is a most important soil constituent for increasing water storage and decreasing the severity of droughts. Organic matter in decay also supplies the largest portion of mineral nutrients needed by growing plants. In fact, the organic matter going through the cycle of decay in the soil is the principal means through which crop production is brought to a maximum.

Corn is the crop which is most exhaustive of the soil as shown by the nitrogen depletion. Corn is followed in order by wheat, oats, and timothy. It appears that the greater the length of time in which there is a growing cover crop on the land and the fewer times the soil is stirred, the less will be the decline of the soil nitrogen and the crop productivity. With perennial and compactly rooted plants, such as timothy, much of the nitrogen carried downward by drainage waters will be absorbed by plant roots and loss from the soil thus prevented.

The effect of continuous cultivation is forcefully illustrated by the continuous corn plot given 6 tons of manure annually. This has a lower nitrogen content than the continuous timothy plot given no soil treatment. Continuous oats with manure has just maintained the soil at the original nitrogen level, while continuous wheat when manured has lost over 12 per cent of the original soil nitrogen in 50 years. Apparently there has been some erosion during the fall and winter on the continuous wheat plots, together with some leaching loss to cause this reduction. The removal of nitrogen by crops has been much less than that returned by the manure. In spite of this, the nitrogen supply in the soil has declined.

Rotations have been less exhaustive of soil nitrogen than any of the single crops except timothy. This would be the expected result since the rotations contain legumes which add nitrogen. In addition the rotations used have kept a growing crop to serve as a cover on the land for a larger share of the time than is the case when corn, or wheat, or oats, are grown continuously. Nitrogen that might otherwise be lost by leaching is caught and

TABLE 2. TOTAL NITROGEN IN SURFACE 7 INCHES OF SOIL AFTER 50 YEARS. (1939). ORIGINAL SOIL CONTAINED APPROXIMATELY 3400 POUNDS OF NITROGEN IN SURFACE 7 INCHES

Cropping system	Soil Treatment	Pounds nitrogen per acre surface 7 inches
Continuous corn	None	1500
Continuous corn	Manure*	2480
Continuous oats	None	2380
Continuous oats	Manure	3370
Continuous wheat	None	2000
Continuous wheat	Manure	2990
Continuous timothy	None	2700
Continuous timothy	Manure	3910
3 year rotation	None	1970
3 year rotation	Manure	3010
4 year rotation	None	2190
4 year rotation	Manure	3060
6 year rotation	None	2220
6 year rotation	Manure	3330

*All manure applied at rate of 6 tons per acre annually.

retained by this growing vegetation. Rotations do not cover the soil as much of the time as does timothy. Reduced soil cover and higher nitrogen loss is also in agreement with the fact that the more often corn occurs in the rotation, the more rapid is the decline of the nitrogen.

Regardless of whether manure has been used or not, the plots in the three-year rotation have the lowest nitrogen content followed in order by the four-year rotation and the six-year rotation systems. Table 2 gives the nitrogen content of soil after fifty years of continuous and rotation cropping.

Monetary Returns From Different Cropping Systems

Any comparisons of soil treatments in terms of their economic returns and the land values they represent must necessarily be influenced by price levels. Nevertheless, when comparable prices, over a definite period (1930-1940), are used for making a conservative estimate of land values, as represented by the crop returns, a relative return may be obtained which might be expected under different cropping systems. The importance of the rotation immediately stands out as shown in Table 3. In the comparisons shown in this table all of the continuously cropped plots excepting timothy have failed to produce any return above labor cost while all of the untreated plots in rotation have produced increases that give a fair return on the investment.

TABLE 3. ANNUAL NET RETURNS PER ACRE (FOR 50 YEARS) OF DIFFERENT CROPPING SYSTEMS. (AVERAGE OF 50 YEARS). NO MANURE OR FERTILIZER APPLIED

Cropping System	Average annual crop value	Labor, Harvesting, Rent	Net annual return/acre	Net land value*
Continuous corn	$11.28	$11.65	$ -0.27	0
Continuous oats	7.75	9.55	-1.85	0
Continuous wheat	9.32	10.10	-0.78	0
Continuous timothy	7.59	6.00	1.59	$ 31.80
Three year rotation	13.02	9.50	3.52	70.40
Four year rotation	15.47**	9.50	5.97	119.40
Six year rotation	11.99	8.50	3.49	69.80

* Using net returns as 5% on investment.
** Value probably too high because of contamination with lime.

TABLE 4. CROP YIELD CHANGES OF FIRST AND LAST 12 YEARS DURING 50 YEAR PERIOD AS A RESULT OF DIFFERENT CROPPING SYSTEMS. ALL PLOTS RECEIVED 6 TONS OF MANURE ANNUALLY

Cropping System	1888-1900	1926-1938	Gain or Loss
Continuous corn	$23.25	$17.30	$ -5.95
Continuous oats	11.68	12.62	+0.94
Continuous wheat	10.74	9.67	-1.07
Continuous timothy	16.82	15.25	-1.53
3 year rotation	22.87	25.42	+2.55
4 year rotation	16.40	20.53	+4.13
6 year rotation	16.34	19.14	+2.80

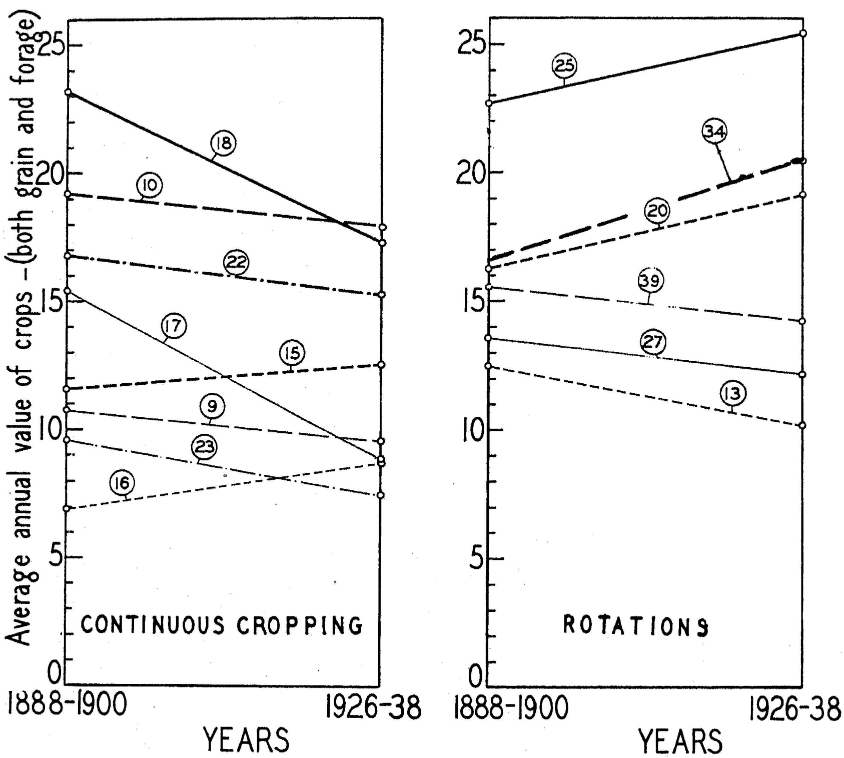

Fig. 8.—Trends in crop yields under continuous and rotation croppings.
Continuous cropping: Plot 9—Wheat, no treatment; Plot 10—Wheat, manure; Plot 15—Oats, manure; Plot 16—Oats, no treatment; Plot 17—Corn, no treatment; Plot 18—Corn, manure; Plot 22—Timothy, manure; Plot 23—Timothy, no treatment.
Rotation croppings: Plot 13—Six-year, no treatment; Plot 20—Six-year, manure; Plot 25—Three-year, manure; Plot 27—Three-year, no treatment; Plot 34—Four-year, manure; and Plot 39—Four-year, no treatment.

Trends in the Crop Yield

In planning for the future productivity of land, a study of the trends of the crop yields during a long period and under various cropping systems is helpful. The monetary values given in Table 4 show whether the trends of the yields during a half century from various cropping systems as followed on Sanborn Field have been upward or downward when considered at the outset and at the close of this long period. For convenience of comparison the various crops have all been converted into money values prevailing during the 1930-1940 period (Figure 8).

By this method of evaluation, the trends in the crop yields under heavy manuring were upward for all rotations. They were downwards for all continuous croppings even where heavily manured, except in the case of oats. Since much higher yielding varieties of oats are now used than was true when the experiments were started, this may offer an explanation for the maintenance of the yield of this crop in the absence of rotation. It is possible that improved varieties of corn and wheat, together with better management practices may have prevented the decline in yield of these crops from being greater than they would have been if the same varieties were still being grown as were used when the experiments were started. Thus the declining soil fertility, as shown by a reduction of crop yields may have been offset by the introduction of the new varieties.

It is also of particular interest to observe that, in the beginning, the continuous corn plot produced the highest yield and the greatest crop value of any of these cropping systems, but the decline in yield in a half century was five times as great as for any other system. The gross crop value of the corn crop on the continuous plot is still above that of oats, wheat, or timothy, but is far below that of all of the rotation plots having similar soil treatment. As an exhaustive agency of soil fertility the trend in the yields of corn indicate that this crop is the most severe.

Planning Rotations in Relation to Soil Fertility

No matter how well planned a rotation may be, rotation alone cannot be expected to maintain crop yields (Figure 8). Rotation of crops is only one factor in lengthening the time the supply of fertility of the soil will last. The use of limestone, manure, and fertilizer, must also be considered. By a proper combination of several or all of these factors, the best cropping results can be obtained and soil productivity maintained at a high level over a long period of time.

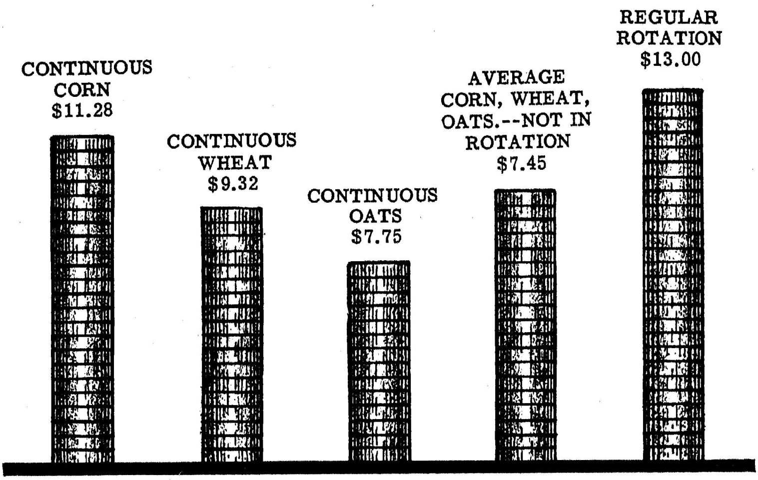

Fig. 9.—Increases in value of crops from planned crop rotations with no soil treatments (average of 50 years).

If lowered production through declining soil fertility is to be prevented, plant nutrients that are removed by cropping must be replaced. If the crops are fed to livestock the manure must be efficiently conserved and applied to the cultivated land as a help in returning soil fertility. If crops are sold, provision must be made to make larger applications of commercial fertilizer and to provide for the growing of green manures, such as sweet clover, so as to supply organic matter and nitrogen.

The kind of rotation to use will depend on many conditions and particularly the differences in crops. The crop sequences are of minor importance so long as proper soil treatments are used and the soil fertility is maintained.

Fig. 10.—Crop rotation increased the yield of corn (average of 50 years). Left to right: Four-year rotation, 47 bu. per acre. Six-year rotation, 49 bu. per acre. Three-year rotation, 44 bu. per acre. Continuous corn, 33 bu. per acre. All plots received 6 tons manure annually.

The following points should be considered in planning a cropping system.

1. *The amount of plant nutrients in the soil cannot be reduced if productivity is to be maintained.* The rotation should be no more intensive than will permit one to maintain the soil fertility.

2. *The most profitable crops may be most severe in demands on the soil.* The most valuable crops usually are the most destructive to soil fertility. They should occur in the cropping scheme no oftener than will permit balancing the plant productivity level. In Missouri, corn is usually the most valuable crop. Corn can be grown more frequently on level, fertile land than on rolling soils or soils of low fertility.

3. *Legumes and sod crops must be included.* Legumes add organic matter and nitrogen to the soil. Both are essential in maintaining soil productivity. The legumes should immediately precede the corn in order to exert their improving effects on the most valuable crop.

4. *Legumes should be grown in all small grains.* Biennial legumes such as sweet or red clover, or a perennial like alfalfa, will be most effective in maintaining fertility where soils have been limed. Lespedeza, an annual legume, will grow in all sections of the state, and although it does better on fertile soils it will furnish much organic matter and nitrogen to the land.

5. *A definite cropping plan should be followed.* This will insure a reasonably constant supply of feed every year. Even if a crop fails one can substitute a crop that will not seriously disrupt the rotation.

6. *Crop rotations through helping to maintain soil fertility will aid in avoiding crop failure.*

7. *Erosion control is necessary.* It is essential that one follow the necessary mechanical practices to control erosion if the cropping system alone will not prevent soil loss.