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Soil Fertility in Relation to Productive Land Value

By

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SUMMARY

The author hopes that readers of this circular will find information of value in the operation of their respective tillable farm lands for the production of all field crops. In the experiment here reported, beans were grown because this crop appeared to be a profitable one for the type of land used in the experiment.

During the 21 years checked in the experiment the growing of crops under normal conditions—that is, relying on rainfall for moisture and reseeding the crop year after year on the same soil—has been shown to be unprofitable. With rotation of crops the yields per acre increased. A further increase was noted when rotation was aided by applications of barnyard manure.

The use of irrigation under the continuous-cropping method was not much more profitable than continuous cropping without irrigation. The substantial gains throughout the period of the experiment were made with rotated crops under irrigation, and especially with rotated crops under irrigation with added applications of manure.

Not only did the yield increase under the latter method, but the water requirement of the soil was almost 50 per cent less than for continuous cropping without irrigation.

The experiment showed that it is far more profitable to keep the soil productive than to restore fertility, as rebuilding exhausted land is a long-time and costly process.

Soil Fertility in Relation to Productive Land Value

By

W. L. Powers
Soil Scientist

A permanent system of agriculture has been found to be the most profitable means of realizing the highest productive value of the land. Such a permanent system calls for developing and maintaining the productive powers of the soil. To this end, crop rotation and use of barnyard manure and farm refuse, producing larger yields and reducing the unit cost of production, have been shown to be effective. Such a program is not only important under present economic conditions, but is advisable for farm operations at any time.

An experiment was started by the author twenty-two years ago to determine the value of crop rotation and barnyard manure for improving the efficiency of irrigation water and increasing net returns.

This circular has for its purpose the presentation of the striking differences found during the experiment affecting yield, composition of the soil, irrigation efficiency, and net profit recorded during a 21-year period.

Organization of experiment. Twelve one-tenth-acre plots of Amity silty clay loam were cropped in a three-year rotation of barley, alsike clover, and navy beans so that four-tenths of an acre of each crop was grown in one block each year. The west half of each block was irrigated. The south half received eight tons of barnyard manure every three years. Two additional plots at the end of the series were included for continuously growing beans. One of these was irrigated, making seven plots that received irrigation. In another series seven plots were cropped by rainfall farming.

Table 1. Average Yield by Three-Year Rotation Periods of White Beans With and Without Irrigation, Rotation, and Manure
Soils Department
Oregon Agricultural Experiment Station

Period	Yields per acre without irrigation			Yields per acre with irrigation		
	Continuous	Rotation	Rotation and manure	Continuous	Rotation	Rotation and manure
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
1914-1916	12.70	11.48	13.70	18.92	15.58	17.34
1917-1919	10.68	14.70	14.75	11.43	18.15	16.98
1920-1922	4.58	7.76	9.45	8.48	10.16	13.07
1923-1925	5.06	10.09	12.32	5.96	16.48	20.17
1926-1928	6.09	11.14	18.97	6.10	23.26	31.82
1929-1931	4.50	7.55	10.97	5.77	12.09	15.37
1932-1934	1.72	5.28	8.33	2.33	9.95	12.94
Average 1914-1934	6.47	9.71	12.64	8.43	15.10	18.24

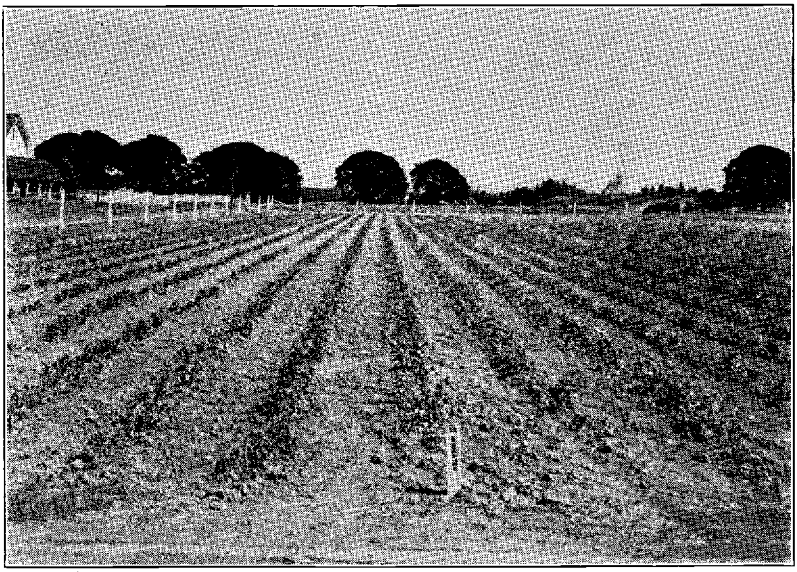

Figure 1. Beans, continuous cropping, 22d crop. The 21-year average yield was 8.42 bushels per acre; net profit $2.64 per acre.

Figure 2. Beans, rotation, irrigation, and manure cropping plan, 22d crop. The 21-year average yield was 18.24 bushels per acre; average net profit $30.31 per acre.

Continuous cropping costly. The average bean yields during the three-year rotation periods throughout the experiment are shown in Table 1. In the three-year period at the start of the 21-year experiment the series of non-irrigated plots produced an average yield per acre of approximately 12 bushels. In the final three-year period of the experiment checked for this circular, 1932 through 1934, the average yield per acre on this area, cropped continuously and dry farmed, was 1.72 bushels.

On the dry-farmed plots throughout the experiment the average yield per acre for rotation alone was 9.71 bushels; for rotation with barnyard manure, 12.64 bushels.

Supplemental irrigation with continuous cropping produced an average yield per acre for the 21-year period of 8.43 bushels. Supplemental irrigation with crop rotation stepped up the average yield per acre to 15.10 bushels. Barnyard manure added to crop rotation and irrigation still further increased the average yield per acre to 18.24 bushels.

Table 2. VALUE OF IRRIGATION, ROTATION, AND MANURE
Soils Department
Oregon Agricultural Experiment Station

Period	Grain yields				Alsike clover yields			
	Dry		Irrigated		Dry		Irrigated	
	Rotation	Rotation and manure	Rotation	Rotation and manure	Rotation	Rotation and manure	Rotation	Rotation and manure
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Tons*	*Tons*	*Tons*	*Tons*
1917-1919	....	....	39.30	49.10	2.09	2.75	4.88	4.13
1920-1922	34.15	42.57	35.72	42.22	2.29	2.90	3.38	4.78
1923-1925	60.58	53.97	51.29	62.00	2.41	2.86	2.76	3.24
1926-1928	34.01	40.17	39.72	42.32	1.83	2.35	3.88	4.41
1929-1931	52.91	66.14	60.61	71.29	3.14	2.90	4.10	3.86
1932-1934	32.60	31.70	36.60	38.97	2.58	2.70	3.42	3.59
Average	42.85	46.91	43.87	50.98	2.39	2.74	3.74	4.00

Manure increases yield. The grain and clover yields, for the records available, are shown in Table 2. Winter barley was commonly grown without irrigation. The new seeding of clover, however, received irrigation after the grain harvest. The increase in grain yield in the irrigated series is due largely to greater crop residues from the irrigation of crops in the rotation. Applications of manure once in three years for the dry series resulted in an average increase in yield of 4.06 bushels per acre.

By manuring, the average clover yield on the unirrigated series was increased from 2.39 to 2.74 tons per acre; on the irrigated series, from 3.74 to 4 tons per acre, a gain of 0.35 and 0.26 tons respectively. Usually two irrigations were applied to the clover; the total depth a season averaged approximately ten inches. The data for these crops are less complete than for the beans as continuously cropped plots were not included. When clover failed, vetch was substituted. In two cases, owing to winter-killing, reseeding with spring grain was necessary.

Irrigation with manure pays. Table 3, presenting the data on net profits and water efficiency, shows that growing beans continuously on the same land was unprofitable. The average loss per acre as computed was 59 cents. From the use of rotation, barnyard manure, and supplemental irriga-

Table 3. RELATION OF SOIL BUILDING TO ECONOMIC IRRIGATION AS SHOWN BY 21-YEAR AVERAGES FOR WHITE BEANS
Soils Department
Oregon Agricultural Experiment Station

Treatment	Depth of water applied	Yield per acre	Gain per acre	Net profit per acre	Gain by irrigation, manure and rotation	Gains per acre inch	Pounds of water per pound of dry matter
	Inches	*Bu.*	*Bu.*				*Pounds*
Beans, dry							
Continuous	----	6.47	------	$0.59*	--------	------	3,003
Rotation	----	9.71	$ 3.24	8.74	$ 9.33	------	2,542
Rotation and manure	....	12.64	6.17	17.18	17.77	------	2,367
Beans, irrigated							
Continuous	3.0	8.43	1.96	2.05	2.64	$0.68	3,496
Rotation	3.0	15.10	8.63	21.26	21.85	7.09	2,850
Rotation and manure	3.0	18.24	11.77	30.31	30.90	10.10	1,949

*Loss.

tion, however, a maximum net profit of $30.31 was realized. The yearly gain resulting from this method of cropping was $30.90. The 21-year average yields and increases per acre as shown in the table were used in arriving at the conclusions concerning the most profitable manner of producing field crops.

A three-inch irrigation was applied when the beans were coming into full bloom. For the total annual cost of this application of water a maximum figure of $1 per acre inch was used. In computing the average net profit or loss per acre the cost of production under rainfall farming was figured at $20 per acre, and a charge of 12 cents a bushel was made for harvesting the increase. The prevailing price of 5 cents per pound or $3 per bushel was used in determining the average crop value.

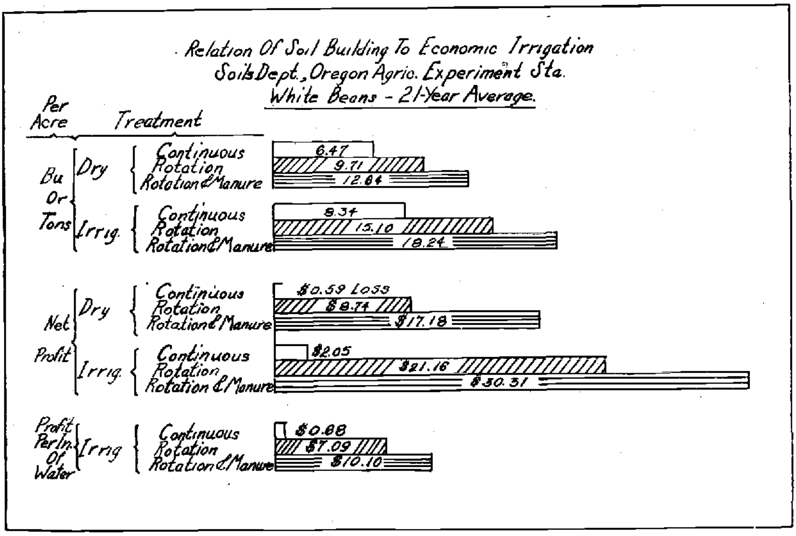

Figure 3. Irrigation with manure is profitable.

The profit per acre-inch of water, as shown in column 7 of Table 3, was as follows: with continuous bean cropping, 68 cents; with rotation, $7.09; with rotation and manure, $10.10. These results are shown diagrammatically in Figure 3.

The twenty-second crop grown on these plots in 1935 yielded as follows: dry, continuous, 3.17 bushels per acre; dry, rotated, 7.67 bushels; dry, rotated and manured, 7.83 bushels; irrigated, continuous, 2.00 bushels; irrigated, rotated, 13.50 bushels; irrigated, rotated and manured, 17.17 bushels.

Water requirement cut in two. The water requirement per pound of dry matter as shown in the last column of Table 3 has been obtained by determining the soil moisture when the crop appeared through the ground and again at the time of harvesting. The loss in soil moisture thus determined added to the rainfall and irrigation has been reduced to pounds in determining the amount of water consumed per pound of dry matter. The water requirement was found to be highest under the continuous cropping plan and almost cut in half for the rotation and manure method.

Soil fertility improved. A chemical study was made of the trial plots after the 20 years of experimentation. Amity silty clay loam is a mature soil developed under a subhumid climate with rather dry summers and an average annual precipitation of 40 inches. The soil is moderately acid, having a lime requirement of approximately 1½ tons per acre and reaction value of pH 5.5, whereas neutrality or the reaction of pure water is pH 7.0.

Organic matter, total nitrogen, and base-exchange capacity were determined by current approved chemical methods.* Blanks run on this acid type indicate that inorganic carbonates were negligible. Subsoils showed small differences in organic matter or plant nutrients in nearly available form.

Table 4. VALUE OF ROTATION, MANURE, AND IRRIGATION FOR MAINTAINING FERTILITY OF SOILS
Bean rotation, irrigation field, Oregon Agricultural Experiment Station.
Corvallis, Oregon

Treatment	Total nitrogen	Organic matter	Base exchange content per 100 grams
	Per Cent	*Per Cent*	*Milli-equivalent*
Beans, irrigated			
Beans continuous	0.165	2.70	7.92
Rotation	0.189	2.60	8.15
Rotation and manure	0.221	3.30	8.32
Beans, dry			
Beans continuous	0.147	2.20	6.46
Rotation	0.174	2.50	7.47
Rotation and manure	0.195	2.60	7.78

Results presented in Table 4 are for soil samples taken from 0 to 7 inches in depth. The gain in nitrogen at plow depth for the rotation and manure method of cropping was more than 1,000 pounds per acre. There was a gain in organic matter of approximately 10,000 pounds per acre at

*Organic matter determinations were made by the modified J. B. Rather method (*Bul.* 140, *Ark. Agr. Exp. Sta.*, 1907) as adopted by L. T. Alexander and H. G. Byers (*Tech. Bul.* 317, *U.S. Dept. of Agr.*, 1932) and base exchange as previously reported J. Agr. Res. 44:97 (1932).

plow depth. There was an increase in the base-exchange capacity due perhaps to the high base-exchange capacity of accumulated humified organic matter, which tends to conserve the soil against degeneration.

Gains or Losses in Plant Food. A balance sheet for the experimental plot giving the highest average yield is shown in Table 5. Nitrogen and sulfur content of the soil was maintained by use of two legumes in the rotation and a manure treatment. A small decrease in phosphorus and potassium was indicated. It may be necessary to supply these elements at a later date.

Table 5. GAIN OR LOSS OF PLANT FOOD IN PRODUCING AVERAGE YIELDS PER THREE-YEAR ROTATION PERIOD.
Oregon Agricultural Experiment Station

Crops produced and fertilizers applied during three-year rotation period	21-year average yield per acre	Plant-food loss per acre				Plant-food gain per acre			
		Nitrogen	Phosphorus	Potash	Sulfur	Nitrogen	Phosphorus	Potash	Sulfur
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Crops									
Beans	18.24 bushels	40	4	12	3	----	----	----	----
Barley	50.98 bushels	43	9	11	3	----	----	----	----
Clover	4.00 tons	----	14	85	7	----	----	----	----
Fertilizers									
Manure (Per acre)	8.00 tons	----	----	----	----	80	16	70	24
Bean straw (Per acre)	0.25 tons	----	----	----	----	6	----	----	----
Total	....	83	27	108	13	86	16	70	24
Balance in plant food consumption	....	----	11*	38*	----	3	----	----	11

*Loss.

Maintaining available plant nutrients. Conserving and building the nutrient supplying power of the soil is an important factor in the successful tillage program. Plants feed upon the nutrients dissolved in the soil water, called the soil solution. Biological activities under favorable conditions such as a moist and neutral soil, well supplied with legume residues, replenish nitrates and sulfates and aid in replenishing phosphate in the soil solution. These elements bring in and hold the nutrient bases in solution, largely from the nearly available or so-called exchange form.

Crop rotation and productive land value. Crop rotation has been 85 per cent as effective as commercial fertilizer in maintaining yields during two decades on silty clay loam soils of the Willamette Valley. This result illustrates the necessity for this type of program on a profitably operated farm. Rotation paves the way for crop diversity, affords steady employment, helps control pests, conserves fertility, aids maintenance of soil organic matter and nitrogen, increases efficiency of irrigation water, systematizes farming, and increases yields with little cash outlay.

Table 6. CROP ROTATION AND PRODUCTIVE LAND VALUE AS SHOWN BY 21-YEAR AVERAGE PRODUCTION FOR BEANS
Oregon Agricultural Experiment Station

Crop	Yield per acre	Net profit per acre	Approximate indicated land value at 6 per cent (Beans data only)
	Bushels		
Beans, dry			
Continuous cropping	6.47	$ 0.59*	....
Rotation	9.71	8.74	$150.00
Rotation and manure	12.64	17.18	300.00
Beans, irrigated			
Continuous cropping	8.43	2.05	35.00
Rotation, after barley and clover	15.10	21.26	350.00
Rotation and manure	18.24	30.31	500.00

*Loss.

Net profit is increased. The average yield of beans and net profit for each method of cropping are listed in Table 6, showing in addition the approximate indicated land value based on 6 per cent on net crop income. Beans grown continuously by rainfall farming for 21 years resulted in a loss and did not return even enough revenue for taxes. Beans continuously under irrigation netted $2.05 per acre or 6 per cent on a land value of $34.17 per acre.

With rotation and dry farming the capitalized valuation is approximately $150 per acre. Under irrigation it is more than $350. For rotation and manuring the return represents 6 per cent on land values or approximately $300 and $500 respectively for unirrigated and irrigated plots.

It is easier and more profitable to keep soil productive than to restore fertility to exhausted land. Soil building is a long-time process. A chemical study of the soils for several of the oldest experiment fields in Oregon and eastern states, recently completed, shows the value of such a soil-building program. The study shows that treatments that have maintained or increased yields—such as lime, legumes, phosphates and manure—have also maintained nitrogen, organic matter, and the base-exchange capacity, and appear to have conserved these soils against degeneration or loss of nitrates and base-supplying capacity.

Based on these studies we may now state the first fundamental law of irrigation practice; namely, that **good fertility renders sufficient the least amount of water and the lowest cost per unit crop.**

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