

*J. C. Hackleman*

UNIVERSITY OF ILLINOIS

# Agricultural Experiment Station

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EUROPEAN PRACTICE AND AMERICAN THEORY  
CONCERNING SOIL FERTILITYBY CYRIL G. HOPKINS

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The increasing price of foodstuffs, the consequent higher cost of living, the decreasing fertility of American soils, and the fact that millions of acres of cultivable farm lands have already been agriculturally abandoned in our Eastern and Southern States should be sufficient to awaken the landowners of Illinois to the necessity of adopting systems of permanent agriculture in this State.

The following letters are published in the hope and belief that they will help to arouse a deeper interest in this most fundamental problem concerning the future prosperity of America, and thus lead all classes of people in this State to make sufficient study of the known facts and principles to enable them to exert influence with such intelligence as will be required to bring about the general adoption of permanent systems of soil improvement while it is still possible to do so.

Briefly, it may be said that the common teaching of the school and press for generations has been most persistent in urging the farmers to practice live-stock farming, in order that the largest possible amount of farm manure should be produced and returned to the land. The importance of good seed, thoro tillage, and crop rotation has also been constantly emphasized; and in recent years the erroneous theory has been advanced by a few men in positions of high authority that the rotation of crops will actually maintain the fertility of the soil.

The following letter was addressed to the Ministers of Agriculture of several European countries, and a similar letter was sent to other leading agricultural investigators and economists in Europe. This correspondence (giving all of the replies received at the date of going to press), and also the letters which follow relating to American agriculture, are self-explanatory.

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UNIVERSITY OF ILLINOIS,  
URBANA, ILLINOIS, U. S. A., DECEMBER 24, 1909.

TO HIS EXCELLENCY,  
THE MINISTER OF AGRICULTURE,  
THE HAGUE, HOLLAND,

SIR:—Statistical records clearly indicate that in your country there has been a large increase in the average yield per acre of wheat and other cereal crops during the last 80 or 100 years,—an increase amounting as a rule to about 100 percent.

We shall esteem it a very great favor if you will be so kind as to inform me about what relative proportion of this increase you would attribute to each of the following factors:

- (1) To the use of improved seed.
- (2) To the use of plant food in commercial fertilizers and stable and green manures.
- (3) To better rotation of crops.
- (4) To more thoro tillage.

Without doubt you have sufficient information concerning the changes that have occurred in your agricultural practice during the last century to enable you to designate somewhat closely the

relative importance of these several factors in effecting the increase over the former yields, and your opinion in this regard will be highly appreciated by us.

With deep respect, I am,

Very sincerely yours,

(Signed) CYRIL G. HOPKINS.

"THE HAGUE, HOLLAND, JANUARY 13th, 1910.

"DEAR SIR:—In reply to your letter of December 24, 1909, I am pleased to inform you that indeed the increase in the average yield per acre of the cereal and other crops in the NETHERLANDS during the last 80 years has been very important. The following figures show that very clearly:

AVERAGE YIELD PER HECTARE IN HECTOLITRES

	1851-1860	1891-1900	1906-1908
Wheat.....	19.3	24.9	32.4
Rye.....	18.0	21.0	23.5
Barley.....	32.8	41.8	46.5
Oats.....	32.4	42.4	50.0
Potatoes.....	120	181	211

"As to your question to inform you what proportion of this increase I would attribute to each of the factors mentioned by you, I am sorry to say that I consider it to be impossible to state these proportions in figures, because a great number of factors, one dependent on the other, have worked together.

"For instance the use of improved varieties of seed has largely contributed to the increase of the yield per acre, but without better manuring and tillage of the soil these new varieties would not have shown any results at all.

"Therefore I can only say that the largest proportion of the increase of different crops in the NETHERLANDS I would attribute to the proper use of commercial fertilizers and to the use of improved varieties of seed, the other factors coming in the second place.

"I am, Dear Sir,

"Yours faithfully,

"FOR THE DIRECTOR-GENERAL OF AGRICULTURE"

(Signed by THE DEPUTY DIRECTOR-GENERAL)

"ROTHAMSTED EXPERIMENTAL STATION,  
HARPENDEN, (ENGLAND),  
JANUARY 17th, 1910.

"DEAR DR. HOPKINS:—I find some difficulty in answering the questions in your letter, because it is impossible to reduce the factors one surmises to have been at work to the state of figures.

"As far as I can come to any conclusions I should say the great increase in production dates from about 1835; it has been almost contemporaneous with the Rothamsted Experiments. Lawes describes the Rothamsted land as yielding on an average 20 bushels of wheat when he took possession; today I should put the average yield as about 36 bushels—I don't think 40 is regularly got.

"The factors at work in the increase have been

- (1) Shrinkage of the area devoted to wheat and other arable crops. The best land has remained under cultivation; the worst has been laid down to grass. The wheat area in England in 1866 was 3,126,431 acres and has become today 1,548,732 (1908). You must allow a 10 to 15% increase in yield per acre on this account.
- (2) Improved seed does not count for very much. We still grow a good many varieties that were known 80 to 100 years ago, e. g. Red Lammas, Rivette, Roughchaff white, and they are still among the good if not the best yielders. I should not put down more than 10% of the increase to the new varieties.
- (3) Better cultivation and tillage. This is a difficult matter to estimate, but from all the accounts that have been handed down to us the progress in cultivation has been toward cheapness rather than towards absolutely better work. For example, the old English wooden plough is still to be found; it does first class work, if anything better than the iron plough, but it requires 4 horses, a man and a boy, where a modern plough will go with one man and two or three horses. Probably there has been some general levelling up to the standard of work of the better farmers, but I should expect the best tillage of 1800 to be no worse than that of today.
- (4) The great factor has been the introduction of fertilizers and purchased feeding stuffs. As soon as you can introduce on a farm some extraneous source of fertility you can raise the standard of production. Of course many of the best farmers buy little fertilizer beyond superphosphate for their turnips; but they bring in fertilizing ingredients all the same in the cotton and linseed cake, the maize, gluten meal, and other cattle foods which are used to a greater extent than fertilizers.

"These of course are only opinions, but in the absence of all statistical evidence they are the best I can give you after a good deal of consideration before of this particular problem.

(Signed) "A. D. HALL".

"ROYAL AGRICULTURAL EXPERIMENT STATION,  
OF THE UNIVERSITY OF GÖTTINGEN,  
GÖTTINGEN, (GERMANY),  
JANUARY 17, 1910.

"HONORED SIR:—You ask me four questions that are very difficult to answer. The four factors operate very differently in the manifold combinations together, as well as upon different kinds of soil.

"When I give you the following figures, as you request, I do it with the feeling that they are open to attack in the highest degree. The estimate is dependent upon every condition. I believe that the principal increase of the harvest is to be attributed in part to the application of artificial fertilizers themselves and in part to their combination with green manures. Thru the application of the two the yield upon the average has been doubled on our common light soils. In some cases the yield has even been increased two and one-half to three fold. Clay soils become tillable to a greater degree when applications of artificial fertilizers are made.

"In general I assume that of the 100% increase in the yield can be attributed:

To artificial fertilizers, 50%.

The effect of artificial fertilizers is increased through the better tillage of the soil. To this cause I attribute 25%.

To the use of better seed, 15%.

To the better crop rotation, 10%.

"However, I repeat, these are my own estimates, the exact basis for which is truly lacking. If these estimates will be of any value to you, it will indeed give me the greatest of pleasure."

"Very truly yours,

(Signed) "VON SEELHORST."

"AGRICULTURAL CHEMICAL EXPERIMENT STATION,  
HALLE A. S., (GERMANY),  
JANUARY 28, 1910.

"HONORED SIR:—The greatly increased yields which we are now producing in Germany, of our different grain crops, especially of wheat, are dependent upon all of the four factors you have named:

1. Upon the use of improved seed.
2. Upon the larger and more intelligent use of fertilizers, especially of artificial fertilizers.
3. Upon a better rotation of crops.
4. Upon more thoro tillage.

"Of these factors, however, the use of fertilizers takes first rank very decidedly in increasing the crop yields. That the yield is also dependent upon the rotation of crops you are of course aware. Thus we harvest, for

example, 60 bushels of wheat per acre on our better lands when manured for a previous potato crop, while this yield could be secured after the gross-feeding beet crop only by heavily fertilizing the wheat.

“Very truly yours,

(Signed) “SCHNEIDEWIND”

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“REPUBLIC OF FRANCE,  
PARIS,

JANUARY 28, 1910.

SIR:—“Under date of Dec. 24” you addressed to me an inquiry with the purpose of obtaining data on the causes of increase during the last 80 years of the yield per *hektare* of cultivated land.

“I have the honor of sending you under this enclosure the elements of a reply to that question, and I am ready at your bidding to furnish you any other information on the matter.

“Accept the assurance of my highest esteem.

“THE MINISTER OF AGRICULTURE”

(BY THE DIRECTOR OF AGRICULTURE)

“In France, the lands suitable to the production of cereals fall, in great part, into two large, sharply defined groups:

- I. Those in which plants of industrial importance, the sugar-beet particularly, occupy a very important place in the rotation of crops.
- II. Those in which plants requiring inter-cultivation are, in general, grown but very little.

#### I. (INTENSIVE AGRICULTURE)

“In the districts devoted to industrial production the farmer has put into practice all known aids to an increase of yield; usually he has carried on his operations methodically. In the first place, he has begun by preparing his land more thoroughly, by deeper tillage and by ridding it of the noxious weeds which infested it. In the second place, due to the larger number of live stock, whose maintenance has been made possible by the residue from industrial processes and by the extension of forage culture, artificial pastures especially (alfalfa, clover, and sainfoin), he has considerably increased the production of farm manure, a commodity which has for a long time been supplemented by commercial fertilizers. These two improvements having once been effected, the introduction of more productive varieties of *stijf-strawed* cereals has become a necessity, because it was found that the old varieties, nourished by too rich a soil, invariably lodged before maturity, and yielded only a very mediocre quality of grain.

“The rotation of crops, in the industrial districts *as well as elsewhere*, has remained practically as it was 50 to 80 years ago. The length of the rotation of crops from the same land, and the order of rotation, has scarcely

varied. The principal fact to be emphasized in this connection is the increasing scarcity in the industrial districts of fallow lands, which have been almost completely replaced by cultivated crops and artificial pastures.

"It is impossible to evaluate with any degree of accuracy, the part which each of these factors has played in the increase of production in cereals, because the result has come from the almost inseparable operation of the combined causes. The effect of fertilizer, for instance, can only be determined in its entirety if the land is very well worked, and if types of soil are selected which are lacking in the particular elements supplied by the fertilizer, and are thereby rendered productive; moreover, the influence of each factor varies between very wide limits, depending upon the nature of the soil and the climate.

"If one is willing to content himself with very approximate figures, we submit in the following table, applying to the districts of industrial agriculture, figures representing, as near as can be determined, the relative importance of the different factors (increase in production taken as 100).

Increased use of farm manure and commercial fertilizers,.....	50 percent at least.
Better preparation of the land.....	30 percent.
Selection of seed and improved varieties.....	15 to 20 percent.

(For oats and barley, which have been less improved by selection than wheat, 20 percent is certainly too high).

## II. (EXTENSIVE AGRICULTURE)

"For the lands of the second group, the farm manures (supplied by live stock becoming each year more numerous as a result of the increased acreage in forage plants, and especially in legumes) play a leading role. Commercial fertilizers are not entirely unknown in the districts comprising this group, but they are often used in insufficient quantities and without sufficient preparation of the land.

"The improved varieties are scarcely adapted to existing conditions there, and the farmer has had the good sense, in many cases, to stand by the old varieties, which are hardier and better adapted to these as yet defective agricultural conditions.

"The scale of efficiency which it seems reasonable to suppose is as follows:

Effect of fertilizers.....	70 percent.
Effect of preparation of land.....	15 to 20 percent.
Effect of selection of seed and improved varieties.....	5 to 10 percent."

"BOARD OF AGRICULTURE AND FISHERIES,

4 WHITEHALL PLACE,

LONDON, S. W.,

1ST FEBRUARY, 1910.

"SIR:—I am directed by the Board of Agriculture and Fisheries to advert to your letter of the 24th December, and to say that while there is no

doubt that a considerable increase has taken place during the last 100 years in the average yield per acre of cereal and other crops in this country, the Board would hesitate to place the increase at so high a figure as 100 per cent, and they are of opinion that 50% would probably be more nearly correct. There are, however, no adequate statistical records prior to 1884, when produce returns were first collected, upon which any accurate estimate of the increase can be based.

"In view of the fact that so many considerations have to be taken into account it is not possible for the Board to discuss within the compass of a letter the relative value of the factors mentioned by you as having contributed to the increase, but, speaking generally, the Board are disposed to attribute the greatest importance to improvements in tillage, including, the drainage of land, and the use of lime. By draining and liming, the texture of the soil has in many districts undergone a permanent change, and the improvement in texture consequent on such operations has rendered possible the use of the improved iron implements now universally employed.

"Next in importance the Board would place the increased supplies of farm manure (enriched by purchased oil cake and other feeding stuffs) and of artificial manures.

"The Board are of opinion that the effect of improved seed has been much less than either of the causes above named. The farmer of 100 years ago selected his seed grain carefully. Some improvement has, however, been brought about—especially in the case of oats—by the introduction of new varieties.

"Changes in rotation have chiefly affected grain crops indirectly by the substitution of green crops for fallow, which has thus increased the manure available on the farm. Cereal crops occupy very much the same place in a rotation as they did a century ago, and while changes in rotation may have been made in order to obtain the full advantage due to improved tillage and an increased supply of artificial manures, these changes should not be regarded as the primary causes of the improvement in the yield of cereals which has marked the past century.

"The Board have dealt only with the points indicated in your letter, but it must be borne in mind that, in addition, there have been other contributory causes, e. g., the general increase of knowledge among the farming community, and the withdrawal of inferior land from arable cultivation owing to the fall of prices.

"I am, Your obedient servant,

(Signed) "T. H. MIDDLETON, ASSISTANT SECRETARY."

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"DEPARTMENT OF AGRICULTURAL CHEMISTRY,  
BACTERIOLOGY, AND PLANT BREEDING,  
KAISER WILHELM INSTITUTE FOR AGRICULTURE,  
BROMBERG, (GERMANY),

FEBRUARY 2, 1910

"HONORED SIR:—According to my view each of the four factors set forth by you has had an essential part in effecting the total increase in

yield. I attribute the largest share to the influence of systematically selected higher yielding varieties.

"The extensive and discriminating use of artificial fertilizers has likewise contributed very essentially to the increase in yield.

"Less important, but always noteworthy is the improvement in the handling of animal manure. Indeed the proper care and best use of animal manure (particularly for hoed crops) is always of great interest, so that its application to the field is without doubt more to the purpose than formerly; but fundamental progress in this line can scarcely be recognized. On the other hand, green manuring, especially in the very humid parts of Germany, has been of great importance and has contributed materially toward the improvement in the culture-condition of the soil.

"Through the introduction of the yellow lupine into Germany in the fifties, and the achievements of Schultz-Luptiz in the eighties, of the last century, very significant progress was made in this line; and it must be granted that about 500,000,000 pounds of nitrogen are annually secured from the air through the activity of the root-tubercle bacteria associated with the legume crops grown in Germany, and for the most part this is turned into the soil. More recently green manuring has also been practiced on the better lands, and with good results.

"Better rotation and tillage have also contributed materially toward the increase in our grain crops. Until the beginning of the nineteenth century the common three-field system\*, with its small yield, prevailed thruout Germany; grass crops having been introduced into the rotation only in certain sections.

"The general adoption of our better rotation systems was brought about by Thaer's work and teaching, in which has been included hoed crops, and in the last decade the greatly expanded sugar-beet cultivation. The heavy soils have thus been greatly improved. Of fundamental importance in successful sugar-beet culture is the condition of the field with respect to moisture and drainage, and in consequence great areas of our arable land have been drained since the middle of the last century, and this improvement has also made possible the higher yields of grain.

"It is difficult to express in figures the relative influence of each of the four factors you have named in bringing about our total increase in yield.

"With highest respect, I remain,

"Very truly yours,

(Signed) "GERLACH."

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"KONIGSBERG I. PR., (GERMANY),  
FEBRUARY 5, 1910.

"HONORED SIR:—Your questions are very difficult to answer within the limits of a letter.

\* This usually means one year of fall-sown grain (as winter wheat or rye), one year of spring grain (as oats or barley or spring wheat), followed by one year of fallow in which more or less weeds are plowed under.—C. G. H.

"The progress of German agriculture has been very marked during the last 30 years. I attempt to answer your four questions briefly as follows:

1. The improvement of seed has had much influence during about the last 10 years, and each year more emphasis is being laid upon seed improvement.

2. The use of commercial fertilizers increases from year to year and they are now more largely used in Germany than in any other European country except Belgium. Commercial fertilizers have contributed very largely to the increase in yield of our field crops. We are striving by their continued use to raise our yields still higher, and this result is slowly but surely being accomplished. We make better use of stable manure than formerly, and green manures are used with good results in sandy soils.

3. The rotation of crops has not changed materially during the last 30 years. In general good crop rotations are practiced, but they have had no great influence upon the increase in crop yields.

4. The better preparation of the soil has been important because deeper cultivation has become more general. This is a matter of much significance in our agriculture.

"Very truly yours,  
(Signed) "STUTZER."

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"AGRICULTURAL EXPERIMENT STATION,  
DARMSTADT, (GERMANY),  
FEB. 10, 1910.

"HONORED SIR:—I have delayed answering your esteemed letter because I wished to send you, with my reply, a little publication, from which you will see that the yields per acre which we have already attained are not those which may yet be secured by more intensive fertilizing. In this publication I have written only regarding the fertilizing of meadows, but in other publications you will observe that there are not only hungry meadows in Germany but also still many hungry fields whose yields may be further increased by fertilizing more heavily.

"It is evident, however, that the increase in yield which may be obtained solely by soil enrichment has a limit, and this limit has already been reached in many cases in Germany. If we wish to secure still larger returns, the result is not to be achieved, on very many farms, only by the application of more plant food; but it will also require better preparation of the soil, the use of the best bred seed of the best varieties, the best care of the crops, eradication of weeds, etc., in order to maintain conditions under which the highest possibility is afforded for the larger amounts of plant food to be transformed into plant substance.

"During the last decade we have been working much in this direction, and with large results also. Machines for the better preparation of the soil have been forthcoming; the weeds are destroyed, the soil is worked better and to a greater depth; and by means of green manures, especially,

the humus content of the soil has been increased. More suitable varieties of plants have been bred, attention has been given to these better bred varieties, investigations have been conducted to ascertain the best amount of seed to plant, the best distance to allow between rows in planting, etc.

"It is difficult to say, however, which factors have contributed most to increase the yields. If one surveys the last 40 years, it can well be said that the increased yield of the first 20 years was produced especially by the use of fertilizers, but during the last 20 years we recognize also the influence of the other factors, which in connection with the ever increasing use of artificial fertilizers have resulted in raising year by year the average crop yields of Germany. We have not yet reached the goal, however. In all lines of agricultural production a significant increase is still possible.

"Very respectfully yours,  
(Signed) "WAGNER."

#### STATEMENT BY PRESIDENT CREELMAN OF THE ONTARIO AGRICULTURE COLLEGE.

The following extracts from an address by President Creelman to the Ontario Agricultural and Experimental Union, December, 1908, is well worthy of careful consideration (Report for 1908, page 62):

##### "SOME OBSERVATIONS OF FARMING IN SOUTHERN EUROPE.

"Italy has been practicing the art of agriculture since the early, early days of the old, old civilization, hundreds of years before the Cristian era began, and agriculture is still the most important industry in Italy, as 85 percent of all the Italian soil is productive land. Dairying is not one of the leading lines, however, nor is any other kind of stock raising. Oxen and asses are still the principal beasts of burden, and wine the largest crop.

"And yet, the agricultural products of Italy are varied, and in the aggregate amount to a very large total. Remember that Italy is only twice the size of the State of New York, and you will realize that not much land is wasted when the following crops are produced annually:

Wheat.....	143,400,000 bushels
Corn.....	85,600,000 bushels
Oats.....	19,360,000 bushels
Rye and barley.....	18,400,000 bushels
Rice.....	26,000,000 bushels
Other cereals.....	18,000,000 bushels
<b>Total cereals.....</b>	<b>310,760,000 bushels</b>
Potatoes.....	19,360,000 bushels
Hemp.....	111,000,000 pounds
Flax.....	30,000,000 pounds
Cotton.....	22,000,000 pounds

Tobacco.....	7,250,000	pounds
Olive oil.....	74,500,000	gallons
Wine.....	666,000,000	gallons

"But like the Swiss and French, the peasant people are a frugal, thrifty race, and while the rich eat wheat bread, the work-people are content with bread made from corn or rye.

"*Legumes everywhere.* In looking about to find how the fertility of the soil was maintained, in districts where live-stock was not common, and hence farm manure was far from plentiful, I noticed that everywhere leguminous crops (or pulse) were the rule. I also discovered that in some form it was eaten every day by rich and poor alike. All the time I was in Italy I never once sat down to a dinner without being served with peas or beans or lentils, or some other variety of leguminous annual. I found also that the poorer classes consume large quantities of pulse, it being used to a large extent as a substitute for meat."

In this connection, the published statistics showing the amount of commercial plant food materials used in Italy are significant. Thus, in 1907, Italy, with a total area of less than 115,000 square miles (about twice the area of Illinois), used 1,050,000 tons of phosphates, 90,000 tons of nitrogen fertilizers, and 7,700 tons of potassium salts. From these data and from the known composition of crops, it will be found that more phosphorus is annually applied to Italian soils than is removed in all the crops produced; and Italy is only following the examples of England, Germany, France, and other countries, which have made large use of bones, marl phosphates, acidulated mineral phosphates, slag phosphate, and phosphatic guanos. Thus, Germany takes about one-third of the phosphate exported from the United States and also imports phosphate from other countries, and besides this, the application of slag phosphate to German soils reached 800,000 tons per annum before the close of the last century.

[NOTE.—The following correspondence is published at the suggestion of the secretary of the Illinois Bankers' Association.]

UNIVERSITY OF ILLINOIS,  
URBANA, ILLINOIS, DECEMBER 21, 1909.

HONORABLE JAMES J. HILL,  
GREAT NORTHERN RAILWAY COMPANY,  
ST. PAUL, MINN.

DEAR SIR:—Referring to your recent correspondence with R. L. Crampton, Secretary of the Illinois Bankers' Association,

it seems to me that it will not be necessary for you to take time to permit me to call upon you personally, unless I fail to make myself understood by letter.

In my judgment you have rendered a greater service to American agriculture during the past few years than any other man. In general, we Americans are sufficiently bigoted so that we refuse to see our own weakness, but you have had the courage and true patriotism necessary to point out the absolute facts concerning our onward rush toward impoverished soils and the consequent destruction of our own prosperity. Even tho the immediate personal interests of yourself and your family are manifestly bound up in the railroad business, you have emphatically stated to the American people that this nation has made the mistake of unduly encouraging manufacture and commerce and other activities that center in cities, at the expense of the farm. I thought when I read those words, and I have stated to others, that they express a noble thought from a master mind, and they must command the admiration and respect of every right-minded man.

On the other hand, there is one page in your article in the November *World's Work* which, with extended dissemination, will, in my judgment, do more damage to American agriculture than all your other efforts will do good; and, when Mr. Crampton said to me that the bankers and the railroad people of the United States were likely to unite in giving to your teaching the widest possible publicity, I told him that you ought to modify some of the statements you have made concerning the remedy for our threatened agricultural condition.

You must realize that the chief interest of Americans in all your efforts is centered in three principles which you have enunciated:

1.—That the farmer should cultivate no more land than he can till thoroly. In the discussion of this principle you emphasize the importance of having smaller farms.

2.—That there should be rotation of crops; and, under this head, you stated that "a proper three or five-year rotation of crops actually enriches the land."

3.—That more general use should be made of farm manure, by means of which, you state, the land may be made and kept a source of perpetual wealth.

Now, whether these principles are right or wrong, you must realize—and I realize—that they will be accepted as right by

practically all who read them. Unquestionably there are many things about the railroad business regarding which you have such absolute knowledge that your opinion is synonomous with the facts. In my own case, I know just as well that some of these statements which you have made are wrong as I know that two plus two do not make five.

The statement which, if not corrected, will do the most incalculable damage to American agriculture, is that "a proper three or five-year rotation of crops actually enriches the land". There is absolutely no more truth in this statement than that the rotation of the check book among from three to five members of the family would actually increase the bank account.

The rotation of crops is, above everything else, a means for the more rapid depletion of the soil. Crop rotation was understood and more generally practiced in Roman agriculture 2000 years ago than it is in America today; and, under the best possible rotations, with large use of legumes, the crop yields of Italy were reduced to a point where the total harvest was equal to only four times the seed.

I have spent much time with the farmers and landowners on the depleted lands of our own eastern states, and it is an absolute fact that most of those lands went down to practical ruin under a good crop rotation. I recently took a legal option on 150 acres of gently undulating upland soil (part of a 500-acre farm) 15 miles from the city of Washington, and 2 miles from a station on the Pennsylvania Railroad, at \$10.00 an acre. I got the history of the land for the last three generations that farmed it. A systematic rotation of crops was practiced, as follows:

- First year, corn
- Second year, wheat
- Third year, timothy and clover meadow
- Fourth year, timothy and clover pasture.

About 10 acres of tobacco were usually grown in the corn field and the tobacco was also rotated with the other crops and, as a rule, grown upon the same four 10-acre fields, corn being grown on 80 or 90 acres each year. Sometimes part of the wheat field was sown to rye, but half of the farm was regularly in timothy and clover. The practice was to sell wheat, live stock, and tobacco. The corn crop, the wheat straw, and the clover and timothy were all used for feed and bedding and pasture, and the

manure produced was highly valued and was regularly applied to the pasture-land to be plowed under for tobacco and corn.

Why did the land deteriorate? Because wheat, live stock, and tobacco are not made out of nothing. The absolute and ultimate chemical analysis of this type of soil shows that it now contains, in the plowed soil of an acre, 7 inches deep, only 160 pounds of the element phosphorus and 1000 pounds of the element calcium; whereas, if such clover crops as we raise on our best treated land in Illinois were to be grown for eight years in succession they would actually require and take from the soil those amounts of phosphorus and calcium.

On our ordinary corn belt land the rotation of crops, with clover grown every three or five years and with all crops harvested and removed, will not add to the soil a pound of any valuable element of plant-food, and plants like animals are made out of food. By rotating crops we avoid the large development of injurious insects which are certain to prey upon any crop grown continuously; we also avoid a similar development of fungous diseases which tend to keep down the yield of any single crop; and the clover roots and stubble supply a small amount of readily decomposable organic matter which, as it decays, liberates from the soil additional supplies of plant food for succeeding crops. But even the clover crop will take from our ordinary corn belt soil as much nitrogen as it leaves in the roots and stubble and its effect upon the soil is purely that of a stimulant.

Certainly we should practice the rotation of crops, not with the understanding that it enriches the land, which is not the case, but because of the benefits above described. We should also make large use of legume crops, in order to secure nitrogen from the air, but, to maintain the supply of nitrogen and organic matter in the soil, these crops must be plowed under, either directly or in the form of manure.

While your first and third principles are in the main not true as amplified, I do not see that their general promulgation will do any particular damage; altho, if it were true that the rotation of crops would enrich the land, there are not many farmers who would care to give serious consideration to your third principle, in which you emphasize the importance of farm manure.

In Illinois we have made a general soil survey of the entire state and we have also made complete detail soil surveys of about

one-third of the counties well distributed over the state. The detail survey covers every 10 acres of every man's farm. You will be surprised to learn that, as a rule, the larger farms in Illinois are better tilled than the smaller farms; but, as a matter of fact, this is what we ought really to expect. Are not the larger railroads better managed than the smaller ones? Are not the larger stores better managed than the smaller ones? Are there not better systems and fewer leaks in the great packing houses than in the small country slaughter houses? As a rule, the larger farms receive the benefit of more brains, larger equipment, more efficient labor, and more systematic and thoroly up-to-date farming generally.

The old saying, "a little farm well tilled" was not originated by an actual farmer or he would have said "a little farm well manured". Such little farms are the market gardens common in the vicinity of our large cities, and it should always be kept in mind that such a farmer is never satisfied with his land until, in the course of six or eight years, he has incorporated with the soil about 200 tons per acre of manure, all made from crops grown upon other land.

All of the domestic animals of the United States, including perhaps 80,000,000\* of cattle, horses, and mules, and about 100,000,000 hogs and sheep, will produce not to exceed 1,000,000,000 tons of manure per annum. This would provide 30 tons per acre per annum for the farm lands of Illinois,† if none were lost. In other words, it would be barely adequate to transform one state into market gardens.

\*Average for the ten years 1899 to 1908 is 80,477,000, including cattle, horses, and mules.

†According to the official statistics of the United States Government, the farm animals in Illinois on January 1, 1910, were as follows:

Horses.....	1,655,000
Mules.....	152,000
Milk cows .....	1,232,000
Other cattle.....	1,974,000
Sheep.....	817,000
Swine (of all ages).....	3,372,000

On the commonly accepted basis that ten head of sheep or swine are equivalent to one head of cattle for manure production, the total live stock on the farms of Illinois are equivalent to 5,431,900 cattle, while the total area of the state is 36,246,000 acres. Thus, there is one such animal to produce manure for every 6.7 acres in Illinois. If none were lost this would provide about 1½ tons of manure per acre per annum, or one-tenth as much

Statistics show that the larger farms on the private estates of Russia produce larger crops than the smaller farms of the peasants; that the farms of India, which average perhaps 3 acres in size, produce from 7 to 12 bushels of corn per acre, and it may be added that crop rotation is the common rule in both Russia and India. Many soils of India are found, upon chemical analysis, to contain only a "trace" of phosphorus, an element that is required in the nucleus of every living cell, plant or animal.

Referring again to the use of farm manure, I have no doubt whatever that there will be less and less of it produced in the United States, in proportion to our food requirements, primarily because the domestic animals destroy four-fifths of the food value of all they consume, thus returning in the form of milk or meat only 20 percent of the nutrient value of the food they eat. No nation can long afford this enormous destruction of food stuffs, with an increasing population and with decreasing crop yields. You are, of course, aware that meat is a luxury in all great agricultural countries, outside of the United States, as in Russia, India, and China.\*

as a 100-bushel corn crop needs, or one-tenth of wheat has been used each year for 66 years on plot 2 of Broadbalk field at Rothamsted, England, concerning which Bernard Dyer has made the following statement:

"It is to be borne in mind, however, that the quantity of dung used in these continuous wheat-growing experiments is, on the yearly average, far less than would be used in practical agriculture on any of the rotation systems."

\*In Sir Henry Gilbert's summary of the "results of very numerous experiments" at Rothamsted, it is shown that 100 pounds of dry matter in the food consumed produced 6.2 pounds increase in the dry substance of cattle, 8.0 pounds in sheep, and 17.6 pounds in swine, including both the edible and non-edible parts of the animals. These data should emphasize the importance of saving and using with the greatest possible care the manure produced in live-stock farming, the value of which may sometime even exceed that of the animal increase, because the total excrements contain, as an average, one-third of the organic matter and three-fourths of the nitrogen and phosphorus originally present in the food consumed. Of course, much of the food consumed by animals, especially by cattle and sheep, is not suitable for human food; but this only raises the question whether a forage crop, such as clover, may sometimes be used with less expense or greater net profit by plowing under as green manure for the production of corn and wheat, than by feeding it for the production of meat and manure. The answer to this question will depend, of course, upon the relative prices of grain, meat, milk, and labor, and upon the technical knowledge or skill and business ability of the farmer as a stockman. Under present conditions, we have a large excess of corn not needed for human food, which is, and in large part must be, marketed thru live stock. Thus for many years, at least (and we hope for all time), both grain and live-stock products must be sold from the farm, and both grain farmers and live-stock farmers must preserve their soils, if general prosperity is to be maintained.

Another point of tremendous importance is that one ton of clover plowed under will add as much organic matter to the soil as will be added by all of the manure that can be produced from three tons of clover fed to animals, even tho none of the manure is lost or wasted; and we should not forget that, of all farm products, animal excrements are probably the most susceptible to loss. About one-half of the value is contained in the liquid excrement and this is almost as difficult to recover as spilled milk. Sufficient absorbent bedding in the older states becomes exceedingly difficult to secure and may even involve greater expense than to grow a crop of clover and plow it under. In other words, there are doubtless conditions under which it is more economical to secure nitrogen directly from the air than to save all of the nitrogen contained in the liquid excrement from animals.

Referring again to the rotation of crops, permit me to call your attention to the fact that the absolute information bearing upon this point is very complete. Thus, a 4-year rotation has been practiced at Rothamsted, England, for 62 years, as follows:

First year, turnips  
 Second year, barley  
 Third year, clover  
 Fourth year, wheat.

If the clover crop failed in any year the bean crop has always been substituted, so that a legume crop has been grown every fourth year on these Rothamsted rotation fields. The soil is normal. The land has been measured, and all of the crops have been weighed. The work has been done in the most careful and most practical way. What are the results? The yield of turnips has decreased from 10 tons per acre, in 1848, to about one-half ton per acre, as an average of the last twenty years. The yield of barley has decreased from 46 bushels per acre, in 1849, to 14 bushels, as an average of the last twenty years. The yield of clover has decreased from 2.8 tons per acre, in 1850, to one-half ton per acre, as an average of the last twenty years. Wheat grown once in four years has been the only crop worth raising on those fields during the last twenty years. The wheat comes after the clover, receives the full benefit of the stimulating action of the clover, and produced 21 bushels, in 1907, and, as an average of the last twenty years, the yield has been 24 bushels, compared with 30 bushels, in 1851, and with 32 bushels average for the first

sixteen years; while the yield has been 38 bushels as an average of the last twenty years where mineral plant food has been applied. Other long-continued investigations support absolutely the results of these Rothamsted experiments.

Do you ask how the smaller European countries, such as England and Germany, maintain their crop yields at a point about double the average of the United States? In large part by the application of American fertility which we export in food stuffs and in phosphate rock. England raises 50,000,000 bushels of wheat and imports 200,000,000 of wheat, 100,000,000 of corn, 800,000,000 pounds of oil cake, and other food stuffs, and great quantities of phosphate from the United States and other countries. Germany raises 125,000,000 bushels of wheat, but Germany consumes 200,000,000 bushels of wheat, and imports, besides, 40,000,000 bushels of corn, more than 1,000,000,000 pounds of oil cake and some other food stuffs, large amounts of phosphate, etc.; while her principal export is 2,000,000,000 pounds of sugar, which contains absolutely no plant food of value. Denmark produces 4,000,000 bushels of wheat and, in addition, imports 5,000,000 bushels of wheat, 15,000,000 bushels of corn, 800,000,000 pounds of oil cake, and large quantities of phosphate; while Denmark exports, principally, 175,000,000 pounds of butter, which contains practically no plant food of value. Belgium raises 12,000,000 bushels of wheat and imports 60,000,000 bushels, etc., etc.

There are three fundamental principles that must be applied, in order to bring about the adoption of systems of permanent agriculture in America:

1. Large use of ground limestone, a natural material which produces no injurious effect upon the soil, which corrects soil acidity and furnishes the element calcium as plant food; and, where needed, dolomite, or magnesian limestone, must be used, in order to supply both calcium and magnesium.

2. The addition of phosphorus in larger amounts than are required to meet the needs of our plant and animal products sold from the farm. Three-fourths of the phosphorus removed from the soil for the production of corn, wheat, or other grain crops is deposited in the grain and thus largely sold from the farm, if the grain is sold; and I call your attention to the fact that grain must be sold. Bread is the staff of life,—not meat or butter. If,

however, the grain is fed to animals, one-fourth of the phosphorus which it contains is, as an average, sold from the farm in the live-stock products, and some of the remaining three-fourths is almost certain to be lost before the manure is returned to the land.

3. The organic matter and an important element of plant food which it contains, namely, nitrogen, must be supplied by making large use of legume crops, which, however, cannot be grown successfully on lands deficient in limestone or phosphorus; and, where one farmer will maintain the supply of nitrogen and organic matter by plowing under farm manure, there must be ten who do the same thing at much less expense and labor by growing and plowing under legume crops.

The deposits of both ordinary and magnesian limestone are inexhaustible in almost every state, and the supply of nitrogen contained in the air at present is sufficient to meet the needs of a 100-bushel crop of corn every year for half a million years, but the supply of phosphorus contained in all normal soils is extremely limited. It is the element which limits the yield of corn and other grain crops, and of clover as well, upon most of the corn belt soils, and it is even more deficient in the soils of the eastern and southern states.

Phosphorus is the master key to the establishment of systems of permanent agriculture upon the soils of the United States. The total known supply of high-grade phosphate in the United States is limited and probably will be exhausted during the next forty or fifty years. Low-grade phosphate deposits are perhaps more extensive and ultimately they must be drawn upon; but as to the ultimate supply of phosphorus, including low-grade forms, there seems to be no very definite information; however, the information is positive and absolute that the element phosphorus is the master key to the preservation of American soils; and, at the present time, the United States is exporting for the paltry sum of \$5,000,000 an amount of phosphorus that would be worth \$1,000,000,000 to our own children in the next generation of Americans. Meanwhile, the United States Bureau of Soils continues to teach the false doctrine voiced in the following direct quotations from Bureau of Soils Bulletin 55, issued February 10, 1909:

"The soil is the one indestructible, immutable asset that the Nation possesses. It is the one resource that can not be exhausted; that can not be used up." (Page 66).

"The soils are not worn out in the sense that they are unable longer to provide mineral nutriments, but the yields are low because, through the prevailing methods, the soils have not been maintained in proper condition." (Page 79).

"As a national asset the soil is safe as a means of feeding mankind for untold ages to come. So far as our investigations show, the soil will not be exhausted of any one or all of its mineral plant food constituents." (Page 80).

"The main cause of infertility or the deterioration of soils is the improper sanitary conditions originally present in the soil or arising from our injudicious culture of crops. It is, of course, exceedingly difficult to work out the principles which govern the proper rotation for any particular soil." (Page 78).

I call your attention to the fact that some investment is necessary if ground limestone or ground rock phosphate are to be applied to the soil, and that poverty makes no investments. Much of the land in the older states is already far past the point of possible self-redemption, and, if we are ever to adopt systems of permanent agriculture in the corn belt, we must begin very soon, while the landowners are still prosperous; for there is practically no other real source of wealth. Even railroad men have no money when dividends fail, and the land alone must be depended upon to actually create wealth.

Of course all will agree that the land should be well tilled, whether in large or small farms, and, also that we should make the best use of all farm manure we can afford to produce; and, if it is an economic possibility, we should adopt methods for preventing the enormous waste of fertility in our city sewage systems; but our greatest danger lies in the general acceptance of the very pleasing and wholly fallacious doctrine that the rotation of crops actually enriches the land; for as soon as clover-failure becomes common in the corn belt because of inadequate supplies of limestone, phosphorus, and humus, even this boasted granary of the world may then have reached a stage of exhaustion beyond possible self-redemption; and, if so, who shall ever redeem the vast areas of depleted American soils?

Just now America is expected to rejoice over the report of the United States Secretary of Agriculture showing that during his administration the aggregate value of farm produce has increased from \$4,417,000,000, in 1898, to \$8,760,000,000, in 1909.

Special emphasis is laid upon the corn crop, the total value of which is unprecedented; but shall we glory in this fact when it is wholly due to increases in price and acreage?

According to the statistics of the United States Department of Agriculture, the area in corn increased from 78 million acres, in 1898, to 109 million acres, in 1909, and the price for a bushel of corn in the United States increased from 28 cents, as an average of the six years, 1895 to 1900, to 47½ cents, as an average for the years 1901 to 1908; while the average yield of corn per acre actually decreased from 25.6 bushels for the twenty years, 1870 to 1889, to 24.9 bushels for the last twenty years, 1890 to 1909, these being the most trustworthy averages obtainable.

The general result is high-priced food for American people, and this calls, not for national rejoicing, but for weeping.

Permit me to add (only in order that, if possible, I may secure your confidence in the absolute truths which I have written) that I have spent half of my life upon the farm; have done all of the ordinary farm work with my own hands; and still own and direct the management of a farm, and do some of the work when I am able to spend a day upon the farm. And let me tell you, also, that Doctor Eugene Davenport, the Dean of the Agricultural College and the Director of the Agricultural Experiment Station of the University of Illinois, spent ten years of his own life in active farm work upon his own farm after he was a graduate of an agricultural college; and that no man can secure appointment to any responsible position in this Agricultural College or Experiment Station who has not had large experience in the actual practice of agriculture, as well as the most fundamental training in science.

With deep respect, I am,

Very sincerely yours,

(Signed) CYRIL G. HOPKINS.

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"ST. PAUL, MINN., DEC. 29th., 1909.

"PROFESSOR C. G. HOPKINS.

AGRICULTURAL EXPERIMENT STATION,  
URBANA, ILLINOIS.

"DEAR SIR:—Your interesting letter is at hand and has been carefully considered.

"It seems to me that your difficulty arises mainly from taking separately and trying to apply singly the three principles laid down in my

article in the *World's Work*. This, of course, can no more be done than you can make the parts of a machine do their work after the machine has been taken apart.

"Your chief objection is to the statement, 'a proper three or five year rotation of crops actually enriches the land,' when thus isolated and considered as in itself a sufficient remedy; which was obviously not the intention.

"Now taking it in just this way, however, it simply states one of those questions where 'doctors disagree.' There is nothing more than a mere academic interest in reviving the controversy of a century ago over the 'humic' and the 'mineral' theories of fertilization. It will not greatly profit agriculture today to thresh over the old straw left by Tull and Liebig. For the same opposite opinions are as ardently held by extremists today. Compare, for instance, the view which you uphold with so much earnestness with that set out in the bulletins of the federal Bureau of Soils which you quote, and elsewhere. Indeed, the theory that crop rotation fertilizes; not that it alone could restore worn-out land, but that, in connection with other improved methods, it creates a higher productivity than the same soil under the same conditions would show if cropped continuously to one product, seems to have abundant support. Bulletins No. 78, of 1898, and 144 of 1901, of the Department of Agriculture, are very explicit on this point, as are practically all the standard works on agriculture and the records of actual experience.

"The danger on either side lies in running to an extreme in order to support a theory. The man who thought nothing but crop rotation necessary would ruin his land by exhaustion and slovenly methods. There is exactly the same result from believing that artificial manures alone are miracle workers. Indeed, the thing itself is ancient history. After Liebig and the Rothamsted experiments had demonstrated the value of artificial fertilizers, farmers and their lands were both bankrupted by assuming that to apply a phosphate was all that was necessary to grow big crops forever. Garnier, writing of agriculture about the middle of the last century, says, 'But while farmers were thus expending their spare capital in the purchase of mineral manures, there was the same strange negligence that we see today in ignoring those fertilizing agents which were ready to hand in and about the holding.' Everybody whose memory goes back fifty years can remember those phosphate-poor farmers and their deteriorating lands.

"Both extremes are undoubtedly ill-advised. The chemistry of the soil is complex, and we are yet only in the infancy of our knowledge of it. The only practical and desirable thing at this time seems to be to recommend to the farmers of the country a system of approved methods, all within their reach, which are simple, easily tried and bound, if used together, to produce far better results than any now obtained in our agriculture.

"These methods are summed up in the three principles which you quote. Of course, if any farmer should choose to select one of them and reject the others, he might be disappointed. They have to be considered and acted upon as a whole, as is made very plain in their statement.

"A great part of your criticism disappears when the third principle is stated correctly, as published. Your letter puts it thus: 'That more general use should be made of farm manure, by means of which you state, the land may be made and kept a source of perpetual wealth.' This is totally different from the printed statement in the World's Work article—'There must be soil renovation by fertilizing; and the best fertilizer is that provided by nature herself—barnyard manure.'

"Please observe that the means stated by which the land may be 'made and kept a source of perpetual wealth' are the three principles set down, and not any one of them or a sentence out of one of them; and even the whole three are not said to be exclusive of others.

"Please notice, further, that the third principle exactly as stated includes your own position as stated in your letter. For it names as one indispensable condition of farm reform 'fertilizing'. The term so used covers every form of fertilizer; barnyard manure being named specifically only as the best. No doubt if the farmers of the country were to spend many millions for other fertilizers, they would get a return; provided they did not make the old mistake of thinking nothing else necessary. But some have not the money to spend, and some will not; while the methods pointed out in my article are within the reach of every farmer in the United States and are of easy adoption in practice.

"I see no reason to change the statement of first principles as made, and cannot think that many farmers will be misled by singling out for adoption one sentence from one of three principles which are presented as inseparable and co-ordinate.

"Very truly yours,

(Signed) "JAS. J. HILL."

UNIVERSITY OF ILLINOIS,

URBANA, ILLINOIS,

JANUARY 3, 1910.

HONORABLE JAMES J. HILL,

GREAT NORTHERN RAILWAY COMPANY,

ST. PAUL, MINN.

DEAR SIR:—I have your letter of December 29, and regret that I have evidently failed to make clear the purpose of my former letter. I certainly had no thought of asking your consideration of any theoretical questions, and I have had in mind only the effect of your three principles of "right methods of farming", taken altogether as a whole. Theories provoke and sustain endless controversy, but right minded men cannot fail to agree ultimately upon established facts, and the facts are surely sufficient in this case, if your time will permit their presentation.

The following direct quotations present your teaching in concise and comprehensive form:

"Right methods of farming, without which no agricultural country such as this can hope to remain prosperous, or even to escape eventual poverty, are not complicated and are within the reach of the most modest means".

"Let us set these simple principles of the new method out again in order:

"First—The farmer must cultivate no more land than he can till thoroly. With less labor he will get more results. Official statistics show that the net profit from one crop of twenty bushels of wheat to the acre is as great as that from two of sixteen, after original cost of production has been paid.

"Second—There must be rotation of crops. Ten years of single cropping will pretty nearly wear out any but the richest soil. A proper three or five-year rotation of crops actually enriches the land.

"Third—There must be soil renovation by fertilizing; and the best fertilizer is that provided by nature herself—farmyard manure.

"Every farmer can and should keep some cattle, sheep, and hogs on his place. It is not in the nature of things that a man on a wheat farm, working four or four and a half months a year, can make as good a living for himself and family, or that he will be as happy over it as if he worked a reasonable portion of the whole twelve months, as if he fed some cattle; as if all his time were employed.\* The farmer and his land cannot prosper until stock-raising becomes an inseparable part of agriculture. The natural increase of animals, the butter and milk, the stock sent to market—all add materially to the income of the farm. Still more important is the fact that of all forage fed to live-stock at least one-third in cash value remains on the farm in the form of manure that soon restores worn-out soil to fertility and keeps good land from deteriorating. By this system the farm may be made and kept a source of perpetual wealth".

\*About 6 million acres of wheat are grown annually in Minnesota, while the total area of the state exceeds 53 million acres. A distinction should be made between the man who raises nothing but wheat, and the general grain farmer who practices a good rotation of crops, adds needed fertility to his soil, raises his own horses, and also some good cows, pigs, and poultry, for family use, besides an abundance of vegetables, fruit, and honey. These were all included in the writer's experience in grain farming; and with the corn-breeding plot, the selecting, testing, cleaning, and treating of the seed, with the repairing and painting of implements and buildings, with winter additions to the woodpile and keeping the boys and girls in school from four to eight months each year, the progressive grain farmer has no more vacation than he needs for study and self-improvement; and even the farm boy's happiness may be as great with two cows as with fifteen. Facilities, preference, and profit are the main factors of influence in deciding between grain farming and live-stock farming, and illustrations of extremes carry no weight as against general facts. With 90 million mouths to feed in the United States, the live-stock farmer must not say to the grain farmer, "We have no need of thee", but both should be encouraged to adopt permanent systems of soil maintenance.—C. G. H.

\*It must be agreed from the known facts that thoro tillage hastens the liberation of plant food from the soil, but adds none to it; that the rotation of crops does not enrich the land, but hastens its depletion; and that we cannot maintain the soils of America by means of the farm manure we can produce.

Even if every man fed all of his crops, saved all of the manure produced, and returned it to the land without loss, it could not maintain the fertility of the soil, because, as stated in my former letter, live-stock products are not made out of nothing. The application of the small amounts of manure produced on the average American farm serves in part to hasten soil depletion. Manure influences crop yields in three distinct ways; first, by furnishing the plant food which it contains, second, by liberating larger amounts of plant food from the soil than would otherwise become available, and, third, by increasing the absorbent and water-holding power of the soil, thus furnishing moisture to the crop, which is thereby enabled to make larger growth, enlarge its root system, and to take still larger amounts of plant food from the soil. (The action of rotting manure on the steel tines of a pitchfork left buried in it for six months well illustrates its power to attack mineral matter). The practice of applying 10 tons of manure containing 20 pounds of phosphorus, and then removing 60 pounds of phosphorus in the crops of corn, oats, wheat, and clover, is a system which leaves the soil poorer in phosphorus after every recurring rotation.

Methods of fertilizing, involving a better knowledge of soil fertility, the intelligent and abundant use of limestone or phosphate or both, and the growing of special green-manure crops for the sole purpose of plowing under for the benefit of subsequent crops, must be classed as complicated or not "within the reach of the most modest means."

The actual condition prevalent in the older parts of the United States is that the farmers whose lands have gone down to practical ruin under thoro tillage, the rotation of crops, and the use of such amounts of farm manure as it is practicable to produce upon the average farm are now too poor to purchase limestone or phosphate or to plow under any crops which could be sold, or fed to live stock.

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\*The preceding statement of "principles" is quoted in full from Mr. Hill's article in *World's Work*, November, 1909, page 12253.—C. G. H.

I meant to present facts rather than theories in my letter of December 21; and I think, if you will read the circulars (105, 123, and 124,) which I am sending you by this mail, you will agree that the so called controversy with the federal Bureau of Soils is easily settled on the sole basis of facts. I call your attention to the fact that there is no general disagreement among "doctors" as to the methods essential for the improvement of the soils. The scientists of Europe and America are in accord with the practice of Europe; and, if the theories of Whitney and Cameron, supported by Secretary Wilson, were promulgated from any ordinary position, they would receive little or no attention, as you may judge from Circular 123.

I also send you our Circular 116, which states concisely the position we have consistently taken with respect to the importance of humus. Personally, I have never known a student of soil fertility who did not emphasize the importance of organic matter.

It was before the time of Christ that Virgil wrote:

"Still will the seeds, tho chosen with toilsome pains,  
Degenerate, if man's industrious hand  
Cull not each year the largest and the best".

Cato also wrote, as follows:

"Wherein does a good system of agriculture consist? In the first place, in thoro plowing; in the second place, in thoro plowing; and, in the third place, in manuring."

Varro wrote:

"The land must rest every second year, or be sown with lighter kinds of seeds, which prove less exhausting to the soil. . . . Horse dung is about the best suited for meadow land.

In the first century after Christ, Columella wrote:

"Some of the leguminous plants manure the soil. . . . Where no kind of manure is to be had, I think the cultivation of lupines will be found the readiest and best substitute."

In spite of this knowledge, which existed two thousand years ago, history tells us that Roman agriculture declined until the produce of the land was only four fold,—until the high civilization of the Mediterranean countries passed into the Dark Ages, which were relieved only by the discovery of the New World, but which still exist for many of our own Aryan race in Russia and India, and which will almost certainly blot out American civilization in the future, if our present tendencies toward land ruin and increase in population continue.

All of us would gladly believe that the use of good seed, thoro tillage on smaller farms, rotation of crops, and the proper use of such amounts of manure as can reasonably be produced would "make room for the new population whose added product will help to restore our place as an exporter of foodstuffs"; but my hope is that you will not encourage the still wider promulgation of this most pleasing erroneous belief.

No consideration of theories is necessary, or even worth while. The established facts are ample,—in the simple mathematical computations relating to supply and requirement of plant food, in the results of careful agricultural investigations by chemical analysis and long-continued field experiments; and in agricultural history and experience, as in the extensive areas of abandoned lands in our own eastern states, including some almost surrounding the National Capitol (referred to in my former letter), and in the enriched lands of Western Europe whose average produce has been doubled during the last 60 or 80 years by systems of positive soil improvement which include, not phosphates alone, but larger and larger use of phosphates.

In Germany the use of slag phosphate exceeded 800,000 tons per annum before the close of the last century, and Germany takes about one-third of our exported rock phosphate, and also imports large quantities from other countries. Even Italy is now applying more phosphorus to her soils than is removed in all her crops. Liebig wrote, regarding the extensive use of bones in England: "Annually she recovers from the shores of other countries to her own the manurial equivalent of three millions and a half of men". As early as 1855, England was also importing annually more than 200,000 tons of phosphatic guano, and twenty-five years ago the importation of mineral phosphates into England exceeded 250,000 tons per annum. England also makes large use of slag phosphate.

What have been the results? Bankruptcy? Phosphate-poor farmers? By no means. As you know, the ten-year average yield of wheat in England is now 32.6 bushels per acre, an increase of 2.5 bushels over the previous ten-year average, compared with 14 bushels as the average of the United States. Likewise, the average yield of wheat in Germany has increased from 22.7 to 28.4, and in France from 17.6 to 20.8 bushels, for the corresponding ten-year averages.

On the other hand, the Norfolk rotation was famous a hundred years ago, not only in England, but also in continental Europe; but, as shown in my former letter, even the Norfolk rotation, the best known in the world, is a means for the rapid depletion of soils.

If we turn to the absolute chemical invoice of the soil, we find as the result of 269 analyses, that the soils of England now contain, as an average, 2230 pounds per acre of phosphorus (soluble in strong acid); while, as the average of many analyses, the most common soils of Illinois contain only 1070 pounds of total phosphorus in the plowed soil of an acre (2 million pounds in each case, corresponding to a depth of nearly 7 inches).

I take it that you desire, primarily, not to encourage American farmers merely to "work the land for all that's in it", which is the absolute essence of more thoro tillage, better rotation of crops, and the return in manure of only a part of the plant food removed, all of which stimulates the soil to yield larger crops for a time, and thus positively hastens ultimate soil depletion. As stated in your letter, the methods pointed out in your article "are within the reach of every farmer in the United States and are of easy adoption in practice", while the absolute enrichment of the soil in phosphorus, which is sold from the farm in both grain and live-stock products (as bone, milk, and meat), and which must be bought to be returned to the land, is not so easy, because, as you state, "some have not the money to spend, and some will not"; and the great danger lies in the fact that those of the latter class will join the former after following only these methods "of easy adoption" for a few more years.

All are agreed that farm manure is good so far as it goes. As much manure should be produced as can be in economic systems, and it should all be saved with care and used to the best advantage; but, if we remove a certain amount of plant food from the soil and return only a part of it in the manure produced, a deficit results, and the net effect of more thoro tillage and the better rotation of crops is to augment the deficit. Where the supply of the essential mineral elements of plant food is practically inexhaustible, these methods of easy adoption may provide a permanent system, but not so with the limited supply of phosphorus in our great areas of level upland soil in the humid parts of the United States.

To one who is striving to encourage the prosperous farmers of the United States to adopt permanent systems of agriculture while they are still able to do so, your letter is, of course, a disappointment, because I am confident that to bring about the general adoption of permanent systems will require the combined efforts of all men of influence. I can easily place in your hands a thousand additional accepted facts, if you wish further information; but I desire not to weary you or to presume upon your kindness.

With deep respect I am,

Very sincerely yours,

(Signed) CYRIL G. HOPKINS.

In conclusion, it may be said that there are at least four factors involved in the solution of the problem of maintaining general prosperity in the United States. These factors may be classified as (1) exploitative, (2) scientific, (3) economic, and (4) legal.

1. The further exploitation of our natural resources, including the remaining virgin soils, as by irrigation and drainage, neither of which is of large significance in comparison with the magnitude of our present agricultural development.

A tendency to over estimate the importance of further exploitation is not uncommon. Thus, in the *World's Work* for February, 1910, even Jas. J. Hill has allowed himself to make the following statement:

"When population reaches a density of 250 to the square mile, which was that of New Jersey in 1900 and was much exceeded by both Massachusetts and Rhode Island, each 100,000 square miles redeemed by irrigation will make room for 25,000,000 additional people."

If we keep in mind that "each 100,000 square miles" corresponds to 64 million acres, the following statements by Frederick H. Newell, Director of the United States Reclamation Service, are of interest for comparison. Director Newell says:

"There is more good land in the arid region than there is water for it. . . . It is known, moreover, that large portions of the water of the arid region cannot be used in irrigation as no irrigable land exists upon which it can be brought at feasible cost."

"If all the run-off waters of this region could be conserved and employed in irrigation, the total reclaimed area might, perhaps, be brought to nearly 60,000,000 acres. . . . With present data, the closest statement is probably under 60,000,000 acres and between 40,000,000 and 50,000,000 acres, including the lands now under ditch."

Since there are 13 million acres now under irrigation in the United States these estimates by the director officially in charge of our irrigation projects are to the effect that somewhere between 27 million and 37 million acres of arid land may still be brought under irrigation. The average of these extremes is 32 million acres, or one-half of 100,000 square miles.

Attention should also be called to the fact that New Jersey, Massachusetts, and Rhode Island do not produce sufficient food for their own people. Even New York, the leading potato state, imports as many potatoes as Colorado produces. New York raises about 400,000 acres of wheat, while Minnesota and Kansas each grow wheat on 6 million acres; New York raises corn on 600,000 acres, while Illinois and Iowa raise about 9 million acres each, and the latest Year Book of the United States Department of Agriculture shows that our corn exports have fallen to only 2.1 percent of our total annual production.

2. The restoration of depleted lands, large increase in productive power of practically all lands now under cultivation, and the permanent preservation of the fertility of all our soils, including even the irrigated lands, which may suffer rapid depletion, especially where reservoir water is used containing no suspended fertility.

This is the only great positive factor, and it will require the application of practical scientific methods.

3. The reduction in the standard of living, by extending the tendency already enforced to some extent, as in the gradual withdrawal of meat and other expensive food products from the daily diet of the common people, and adopting such standards as are common in China and Japan, where beef, butter, and milk are practically unknown foods.

4. The legal control of increase in population by the enactment and enforcement of just and necessary laws relating not only to immigration but also to limitations upon the reproduction of the less fit of human kind, including every form of degeneracy, whether revealed by criminality, insanity, beggary, or any other weakness—mental, moral, or physical. An enlightened humanity must grant to all the right to live, but the reproduction of the unfit can never be an inherent and inalienable right. Without the application of this legal factor there can be no assurance of the permanent maintenance of prosperity and high civilization in this country.

**WE ARE** interested in preserving the fertility  
of the soil in this country **ARE YOU?**

Resolution unanimously passed by the Executive Council  
of the Bankers' Association, January 26, 1910

RESOLVED: That it is the sentiment of the Bankers' Association of the State of Illinois that the recommendations of President James and Professor Cyril G. Hopkins of the University of Illinois as to:

## The Preservation of the Soil in this State

be acted upon by the members of the Association through requesting their officers and directors to use their influence to secure more general recognition of

## The Necessity of Returning to the Soil the Essential Elements Removed by Repeated Cropping

to the end that the most valuable asset of the State may be saved from deterioration by early action on the part of land owners and farmers.

It is further

RESOLVED: That information obtained on this subject be furnished to Banks, members of the Association.

The Bankers' Association of the State of Illinois, realizing the importance to the State and Nation of a successful agriculture, and that the interests of the banks and farmers are identical, wish to do anything they may in the way of helping the farmers to improved methods, better yields and better prices.