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Utah Agricultural College
EXPERIMENT STATION

Bulletin No. 109

**The Nitrogen
and Humus Problem in
Dry-Land Farming**

BY
ROBERT STEWART
Logan, Utah, Aug. 1910

The Utah Agricultural Experiment Station

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The Nitrogen and Humus Problem in Dry-Land Farming

By ROBERT STEWART.

The effect of cultivation and the growth of crops upon the nitrogen and humus content of soils has been studied by various investigators, both in America and Europe. In general, the results of the various investigations indicate that cropping and cultivation are very destructive of the organic matter and the nitrogen of the surface soil.

Berthelot,¹ in 1886, reported that the carbon and nitrogen content of calcareous clayey soil, originally very deficient, was gradually increasing owing to the action of diatoms.

Deherain² found that the soils from plots which had not been manured had lost over 50 per cent of their carbon. The light soil of Grignon lost nitrogen in excess of the amount removed by the crops. The loss of carbon was due to the decomposition of the organic matter, while the greater loss of nitrogen was due to drainage.

Snyder³ found that in the humid section in grain cultivated soils there is a rapid decline of the vegetable and animal matter, and a loss of the element nitrogen. According to Snyder the nitrogen was lost not only by the removal of the nitrogen in the crop, but that drainage and denitrification played very important parts in its loss. Snyder also found that summer fallowing⁴ was more destructive to the nitrogen and humus content of the soil than was the continuous cropping to wheat. When summer fallowing was practiced, six

1 Compt. rend.; (1886), tome 102, p. 951.

2 Compt. rend.; (1889), tome 109, p. 781.

3 Minn. Exp. Sta. Buls. 30, 41, 53, 65, 70 and 94.

4 Bul. 70, Minnesota Exp. Sta., p. 260.

times as much nitrogen was lost by other processes as would have been removed by the plant as food.

Ladd² found that long continued cropping of land with wheat by the fallow process was very destructive to the nitrogen content of the soil.

Alway,³ in 1909, reported that fields in Nebraska which had been long under cultivation showed a great loss of nitrogen, humus and unhumified organic matter. He says: "The greatest losses of organic matter, nitrogen and humus have been caused either by the washing or by the blowing away of the surface soil."

Alway and Vail,⁴ in 1909, reported the accumulation of nitrogen in a prairie soil due to the deposition in rifts of organic matter by the wind.

Alway and Turmbull,⁵ in April, 1910, reported on the loss of nitrogen in cropped land when compared with adjacent virgin land. They found that the loss of nitrogen, humus and organic matter in twenty-five years was about one-third of the amounts originally present in the prairie soil. In certain cases they found that the content of nitrogen, humus and organic matter in the long cultivated soil was slightly higher than in the virgin soil, which they attributed to the difficulty of obtaining samples of virgin soil which correctly represented the original composition of the cultivated field. The observed loss of nitrogen, humus and organic matter in the cultivated soil is due to two causes, oxidation of the organic matter and erosion by the wind.

At the same time Bradley⁶ reported a study of the virgin and cropped soils of Eastern Oregon. He found that while the nitrogen content of the soils which had been cropped for about twenty-five years was about the same as that of the adjacent virgin land, the carbon content had decreased to a marked extent.

2 Bul. 24, North Dakota Exp. Sta.

3 Bul. 111, Nebraska Agric. Exp. Sta., p. 10.

4 Jr. of Ind. & Eng. Chemistry, vol. I, 1909, p. 74.

5 Jr. of Ind. & Eng. Chemistry, vol. II., 1910, p. 135.

6 Jr. of Ind. & Eng. Chemistry, April, 1910, vol. II, p. 138.

Headden,¹ in February, 1910, reported the accumulation of nitrogen in the form of nitrates in some Colorado soils. This accumulation of nitrogen he believed to be due to the fixation of free nitrogen of the atmosphere by micro-organisms.

EXPERIMENTAL PART.

In view of the known action of continuous cropping and summer fallowing upon the nitrogen and humus of humid soils, a knowledge of the effect of dry-farming upon the nitrogen and humus of dry-farm soils became of exceedingly great importance. With this idea in view the author, in the summer of 1907, had a survey made of the dry-farming area in Cache Valley, the oldest extensive dry-farming district in the State. Some of the farms of this district have been under cultivation for forty-five years, and apparently yield as good crops as they ever did. The important principle of dry-farming is summer fallowing for the purpose of conserving the moisture of the soil. According to all the teachings of the humid agricultural districts, as noted above, the practice of this principle, while it conserves the moisture of the soil, is also ideal for the destruction of the organic matter of the soil, with the resulting loss of nitrogen.

The survey was started with the hope of learning something regarding the effect of crop production and summer fallowing upon the humus, nitrogen and nitric nitrogen of the soil. The results obtained were so opposite to the teachings of the humid agriculturists and so significant that the author felt that they should be confirmed by further work before publication, but the publication of recent articles on the same subject by other investigators has led the author to believe that these results would be of immediate interest to others working along similar lines. More extended studies of the soils of the dry-farming sections of the State are being made at present, but only the results now available are reported.

1 Bul. 155, Colorado Agricultural Experiment, February, 1910.

The soils studied are derived from the nearby mountain ranges, which are composed largely of limestone and quartzite. Cache Valley was at one time Cache Bay of old Lake Bonneville. The erosion of the nearby mountain ranges loaded the mountain streams with finely divided particles of limestone and quartzite, and when the running waters of the streams met the quiet waters of Cache Bay the streams deposited their loads. It is of this material that the soils of the dry-farming area of Cache Valley are composed.

The plan of the experiment called for a careful examination of the individual farms of the section and careful sampling in several places of the cropped land and also of the adjacent virgin soil. The soil was sent to the chemical laboratory and the nitric nitrogen determined immediately by the phenol-disulphonic acid method. The moisture was also determined in order to convert results for nitric nitrogen to the dry basis. The samples were then air dried and preserved for the determination of total nitrogen and humus. The total nitrogen was later determined by the Kjeldahl method and the humus by the methods of the Official Agricultural Chemists.

Green's farm, southeast of Hyrum, had been under cultivation for twenty-three years. The results obtained from a study of this farm are given in Table 1.

The oat and wheat land had been cropped continuously for twenty years, with the exception of one year fallow. No information could be obtained regarding the length of time the alfalfa or the oat land had been cropped. The land cropped to potatoes had been in vegetables for twenty-three years and had received some barnyard manure. A study of the results obtained for the first foot indicates that in the land which had been continuously cropped to wheat and oats for twenty years the nitrogen content had decreased, while the humus content had remained practically constant. Cropping to alfalfa or oats alone had decreased both the nitrogen and humus content. The increase in the potato land is explained above. The amount of nitric nitrogen is low in all cases. A study of the second foot shows that the nitrogen content of all the

cropped land except the potato land is lower than the adjacent virgin soil. The depressing effect of alfalfa upon the nitrogen and humus content of the soil is noteworthy.

The nearby Riter farm had been under cultivation for twenty years; it had been cropped continuously for seventeen years and was summer fallowed for the first time in 1905, planted to wheat in 1906 and was being summer fallowed in 1907 at the time of taking the samples.

TABLE 1—GREEN'S FARM, SOUTHEAST OF HYRUM.

Results for total Nitrogen and Humus reported as per cent of Dry Soil.*

Results for Nitric Nitrogen reported as parts per million of Dry Soil.†

No of Analyses	Depth of Sample	Length of Cultivation	Crop	Total Nitrogen	Nitric Nitrogen	Hu-mus
2	0-12	20 years	Oats and wheat	0.202	0.77	3.08
3	0-12	Virgin	Weeds and wild grasses, sagebrush ..	0.216	0.97	3.20
1	0-12	?	Alfalfa	0.158	0.46	2.76
1	0-12	?	Oats	0.150	0.15	2.80
1	0-12	23 years	Potatoes	†0.356	2.10	4.51
2	12-24	20 years	Wheat	0.142	0.44	3.37
3	12-24	Virgin	Sagebrush ...	0.2572	0.61	2.88
1	12-24	?	Alfalfa	0.0970	0.69	1.93
1	12-24	?	Oats	0.1012	0.34	2.74
1	12-24	23 years	Potatoes	0.2932	1.05	3.29

*The results in all of the tables following are reported in the same way.

†Garden patch, manured.

TABLE 2—RITER'S FARM, SOUTHEAST OF HYRUM.

No of Analyses	Depth of Sample	Length of Cultivation	Crop	Total Nitrogen	Nitric Nitrogen	Hu-mus
12	0-12	20 years	Wheat	0.184	1.3	2.48
3	0-12	Virgin	Sagebrush, blue grass . .	0.150	1.0	1.70
9	12-24	20 years	Wheat	0.1683	0.85	2.07
3	12-24	Virgin	Sagebrush . . .	0.1674	0.77	1.54

The continuous cropping to wheat had increased the nitrogen content of the first foot over the adjacent virgin land to a marked extent. The results for the cropped wheat field is the average of twelve determinations, and is therefore reliable as indicating the true nitrogen content of the field. In case of the second foot the nitrogen content of the cropped and virgin land is practically the same, while the humus content of the wheat land is higher than the adjacent virgin soil.

The Christensen farm is in the same section. The part cultivated to alfalfa and wheat for fourteen years was planted to wheat one year and then to alfalfa, and was in alfalfa at the time of taking the sample in 1907. The wheat land was cropped continuously every year to wheat for twenty-three years; summer fallowing was not practiced. The adjacent virgin soil was in sagebrush and wild grasses.

TABLE 3—CHRISTENSEN'S FARM, SOUTHEAST OF HYRUM.

No of Analyses	Depth of Sample	Length of Cultivation	Crop	Total Nitrogen	Nitric Nitrogen	Hu-mus
3	0-12	14 years	Wheat and alfalfa	0.177	1.3	1.87
2	0-12	Virgin	Sagebrush	0.226	0.37	2.72
3	0-12	23 years	Wheat	0.315	0.38	2.77
1	12-24	14 years	Wheat and alfalfa	0.1119	0.11	1.94
1	12-24	Virgin	Sagebrush	0.1703	0.27	1.73
2	12-24	23 years	Wheat	0.1647	0.20	3.31

A study of the first foot samples indicates that the continuous cropping to wheat has increased the nitrogen content

over that of the adjacent virgin soil, while the humus content is practically the same. The growing of alfalfa has decreased the nitrogen and humus content. In case of the second foot both the wheat and alfalfa have caused a decrease of the nitrogen content of the soil.

The district between Wellsville and Mendon is more rocky than the Hyrum section. The wheat land has been summer fallowed two or three times during the last ten years. The results obtained from a study of this district are given in Table 4.

TABLE 4—DISTRICT NORTH OF WELLSVILLE.

No of Analyses	Depth of Sample	Length of Cultivation	Crop	Total Nitrogen	Nitric Nitrogen	Hu-mus
3	0-12	13-20 yrs.	Wheat	0.215	0.21	2.33
2	0-12	Virgin	Sagebrush	0.186	0.13	2.52
2	12-24	13-20 yrs.	Wheat	0.1545	0.09	2.68
2	12-24	Virgin	.....	0.1575	0.08	1.74

Again the nitrogen content of the first foot of the wheat land is higher than that of the adjacent virgin soil. The humus content is practically the same. The nitric nitrogen is low. In case of the second foot the nitrogen content of cropped and virgin soil is nearly the same. The humus content of the virgin land is lower than that of the cropped. The nitric nitrogen content is low.

Petersboro is the pioneer dry-farming district of Cache Valley. The Benson farm is one of the newer farms. It has been under cultivation fifteen years. It has been summer fallowed alternately since breaking up. The results obtained from a study of this farm are given in Table 5.

TABLE 5—BENSON'S FARM IN PETERSBORO.

No of Analyses	Depth of Sample	Length of Cultivation	Crop	Total Nitrogen	Nitric Nitrogen	Hu-mus
4	0-12	15 years	Wheat	0.207	0.34	2.99
2	0-12	Virgin	Weeds	0.162	2.62	1.79
4	12-24	15 years	Wheat	0.1453	0.79	2.78
2	12-24	Virgin	Weeds	0.1583	4.55	2.06

The cropping of this farm to wheat has caused an increase in both nitrogen and humus in the first foot over that of the adjacent virgin soil. The nitric nitrogen content of the virgin land is greater than that of the cropped land. In case of the second foot the nitrogen content of the cropped land is lower than the virgin, while the humus content is higher.

Peterson's farm in Petersboro has been planted to alfalfa and wheat. The alfalfa land has been in alfalfa for seventeen years while the wheat land was cropped alternately with summer fallow for eight years. The results of this study are given in Table 6.

TABLE 6—PETERSON'S FARM IN PETERSBORO.

No of Analyses	Depth of Sample	Length of Cultivation	Crop	Total Nitrogen	Nitric Nitrogen	Hu- mus
2	0-12	17 years	Alfalfa	0.245	0.41	2.41
2	0-12	Virgin	Slough grass..	0.325	0.25	3.39
1	0-12	8 years	Wheat	0.3236	1.82	3.35
2	12-24	17 years	Alfalfa	0.1629	0.42	1.89
2	12-24	Virgin	Slough grass..	0.2684	0.20	2.32
1	12-24	8 years	Wheat	0.2275	0.41	2.58

The cropping to alfalfa has caused a decrease of the nitrogen and humus content over that of the adjacent virgin soil. The alternate cropping of the land to wheat with summer fallow has apparently not affected the nitrogen or humus content.

In case of the second foot the alfalfa land is markedly lower in nitrogen and humus when compared with the adjacent virgin soil. The wheat land is lower in nitrogen, but there is no appreciable difference in the humus content.

Ahrnes' farm in Petersboro had been cropped to alfalfa for seventeen years, and was cropped to wheat for the first time in 1906. It was growing its second crop of wheat at the time of sampling. The results of the study are given in Table 7.

TABLE 7—AHRNES' FARM IN PETERSBORO.

No of Analyses	Depth of Sample	Length of Cultivation	Crop	Total Nitrogen	Nitric Nitrogen	Hu-mus
2	0-12	18 years	Wheat, alfalfa	0.2266	5.10	2.60
1	0-12	Virgin	.....	0.280	0.31	2.9
1	12-24	18 years	Wheat, alfalfa	0.2306	0.34	3.56
1	12-24	Virgin	.....	0.2059	0.23	2.72

The nitrogen content of the cropped land is lower than the adjacent virgin in the first foot, while the humus also is slightly lower. In the second foot the nitrogen and humus of the virgin soil is lower than the cropped land.

On the Partington farm wheat was raised for fourteen years, the land being cropped alternately, after which the land was cropped to alfalfa for nine years. A second field had been in alfalfa for an indefinite period. The results of a study of this farm are given in Table 8.

TABLE 8—PARTINGTON'S FARM IN PETERSBORO.

No of Analyses	Depth of Sample	Length of Cultivation	Crop	Total Nitrogen	Nitric Nitrogen	Hu-mus
1	0-12	?	Alfalfa	0.1860	0.38	2.00
1	0-12	23 years	Alfalfa and wheat	0.1699	0.43	1.93
1	0-12	Virgin	Grass and weeds	0.2217	0.27	2.68
1	12-24	.....	Alfalfa	0.1124	0.33	1.35
1	12-24	23 years	Wheat, 14; alfalfa, 9	0.1078	0.61	1.50
1	12-24	Virgin	.....	0.1465	0.26	1.78

In both the cropping to alfalfa and cropping to alfalfa and wheat the nitrogen and humus content is lower than that of the adjacent virgin soil.

The nitrogen of the soil of the second foot in both fields is lower than that of the virgin soil, while the humus of the field cropped to alfalfa and wheat is higher than that of the virgin.

On Edward's farm the one field was cropped to wheat continuously for thirteen years and then alternately during the last ten years. The second field has been cropped for an indefinite period. The results of this study are given in Table 9.

TABLE 9—EDWARD'S FARM IN PETERSBORO.

No of Analyses	Depth of Sample	Length of Cultivation	Crop	Total Nitrogen	Nitric Nitrogen	Hu-mus
1	0-12	23 years	Wheat	0.1944	0.47	1.86
1	0-12	.....	.....	0.1908	0.57	2.23
1	0-12	Virgin	Grass and weeds	0.1623	0.31	1.62

In both cases the nitrogen and humus content of the cropped land is greater than that of the adjacent virgin soil.

The Farrell farm is the pioneer dry farm of Cache county. Part of it had been cultivated for forty-one years at the time of the study. One field had been cropped to wheat alternately for sixteen years, then to alfalfa for six years, and then to wheat for the past ten years. The other two fields had been cropped to wheat for thirty and forty years respectively by the alternate wheat and fallow method. The results are given in Table 10.

TABLE 10—FARRELL'S FARM IN PETERSBORO.

No of Analyses	Depth of Sample	Length of Cultivation	Crop	Total Nitrogen	Nitric Nitrogen	Hu-mus
1	0-12	30 years	Wheat	0.1602	0.45	2.62
1	0-12	41 years	Wheat	0.1964	0.97	2.55
5	0-12	Virgin	Grass and weeds	0.1755	0.39	1.98
1	0-12	31 years	Alfalfa and wheat	0.1840	0.34	2.60
2	12-24	30 years	Wheat	0.1269	0.80	1.83
1	12-24	41 years	Wheat	0.1816	1.07	2.56
2	12-24	Virgin	.....	0.1521	0.30	1.64
1	12-24	.....	Wheat	0.1037	0.34	1.60
1	12-24	31 years	Wheat, 25; alfalfa, 6	0.1134	0.19	1.77

The nitrogen content of the first foot of the land cropped for thirty years is slightly lower than that of the adjacent virgin soil, while the humus is higher. The land cropped for forty years has a higher nitrogen and humus content, as does also the land cropped to alfalfa and wheat.

In the second foot the nitrogen of the land cropped for thirty years is lower than that of the virgin soil, while the humus is practically the same.

The nitrogen and humus content of the soil of the field cropped for forty-one years is higher than that of the virgin soil. This is also true of the land cropped to alfalfa and wheat.

SUMMARY.

While the data submitted here are insufficient from which to draw sweeping conclusions, there are certain facts which are brought out by a study of the individual tables. In land cropped to wheat, either continuously or by the summer-fallow method, the nitrogen and humus of the surface foot tends to remain constant or to slightly increase over that of the adjacent virgin soil.

In Table 11 will be found the results obtained by taking an average of all the determinations made on the wheat, virgin and alfalfa land studied.

TABLE 11—SUMMARY OF RESULTS.

Results for Total Nitrogen and Humus reported as per cent of Dry Soil.

Results for Nitric Nitrogen reported as parts per million of Dry Soil.

Crop	Depth of Sample	No. of Analyses	Total Nitrogen	Nitric Nitrogen	Humus
Wheat	0-12	27	0.2055	0.80	2.67
Virgin	0-12	22	0.1984	1.04	2.45
Alfalfa	0-12	11	0.2009	1.74	2.27
Wheat	12-24	24	0.1466	0.76	2.45
Virgin	12-24	19	0.1823	1.38	1.99
Alfalfa	12-24	11	0.1604	0.60	1.73

The nitrogen content of the first foot of either the wheat or alfalfa land is higher than that of the virgin. The humus content of the wheat land is slightly higher, while that of the alfalfa land is lower. The nitric nitrogen content varies from 0.80 parts per million in case of the wheat land to 1.74 parts in the alfalfa land.

In the second foot the nitrogen of either the alfalfa or wheat land is lower than that of the virgin soil. The humus of the wheat land is higher than that of the virgin soil, while that of the alfalfa is lower. All three of the constituents decrease with depth of the sample. This table summarizes and emphasizes the above statements.

In studying the results given for an explanation of the phenomenon noted, several explanations suggest themselves.

In the first place, the assumption is made that the composition of the virgin soil now correctly represents the composition of the cultivated soil before the beginning of cultivation. The impossibility of obtaining a sample of virgin soil which even approximates the original composition of the soil is obvious. The uniformity of the results obtained on so many samples over such a large district would seem, however, to indicate that this would not explain all of the phenomenon noted.

In the second place, a part of the increase in nitrogen in the first foot may be accounted for by causes similar to those which cause the "rise of the alkali" in arid regions. This, however, is hardly probable, and if it has any influence at all it would be very slight.

Again, it is possible that azotobacter, or other microorganisms which fix the free nitrogen of the atmosphere, are in great abundance in our arid soil and fix the free nitrogen of the atmosphere to a relatively great extent. The soil as noted offers a favorable medium for the growth of bacteria. In our study of the influence of irrigation water upon the movement and production of nitric nitrogen, carried on in cooperation with Dr. Kellerman of the Bureau of Plant Industry, McBeth and Allen working under the direction of Dr. Keller-

man, have reported that the azotobacter may be isolated with relatively great ease and in large numbers from the soils of Cache Valley. It is possible that this may have considerable influence upon the results obtained. This is a line along which further work should be done.

The last and most probable explanation which suggests itself is the following: The method of successful dry-farming for conservation of the limited moisture supply and the demands of the plants for water causes their roots to penetrate to a far greater depth than similar plants in a humid climate. The feeding range of the plant for plant food is thus increased. The plant probably gets a greater supply of its nitrogen from below the first foot than a similar plant would in a humid climate. The wheat also is harvested by a header, and practically all of the straw containing nitrogen derived from below the first foot is added to the surface foot. This greatly increases the nitrogen and humus content at the expense of the lower foot section.

The data presented herein is very interesting and instructive, but one must not generalize too much from the limited amount of information furnished. In studying the results, the nature of the soil and the cultural methods of Cache Valley should be kept in mind. The soils being derived almost without exception from limestone and quartzite, are rich in calcium and magnesium carbonates. Such soils are probably not found in any other extensive dry-farming district outside of Utah. Interested students may learn more of the nature of the soils by a study of the soils of Cache Valley as reported by Dr. Widtsoe.¹ The cultural methods noted above should also be kept in mind in a study of the results obtained.

ACKNOWLEDGEMENT.

The author wishes to acknowledge his indebtedness to Mr. F. D. Farrell, who made the survey and who made the nitric nitrogen determinations; to Mr. W. L. Walker, who made the

¹ Bulletin 52, Utah Experiment Station.

nitrogen determinations, and to Mr. F. S. Harris, who made the humus determinations.

CONCLUSIONS.

1. The cropping of dry-farming land in Cache Valley to wheat, either by the summer fallowing method or by continuous cropping, does not decrease the nitrogen or humus of the surface foot of soil.

2. The second foot of grain cropped land contains less nitrogen and humus than does the second foot of the adjacent virgin soil.

3. The cropping of dry-farm land to alfalfa causes a decrease of the nitrogen and humus over that of the adjacent virgin soil.

4. The observed phenomenon in case of the grain cropped land is probably due to the addition of nitrogen to the surface foot from lower depth and the addition of the humus from the added straw.

5. The work of this Bulletin indicates that in a study of the nitrogen problem in dry-farming attention must be paid to greater depth of soil than the traditional ploughed surface.