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THE IMPROVEMENT OF SANDY SOILS

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by

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The Improvement of Sandy Soils.

The problem of successful farming and maintenance of fertility on sandy soils is one with which many farmers in the state are very seriously concerned. "When we consider that approximately three million acres of this kind of land is now in farms under cultivation, and that the fertility of these soils is easily exhausted, we begin to realize the value of systems of farming which will tend to increase rather than decrease the amount of plant food in the soil"[1]. It is the object of this paper to discuss some of the factors which are necessary to successful farming on these soils, and to suggest systems of farming which will aid the farmer in securing larger and better yields of the ordinary field crops.

Most of the experiments upon which many statements in this paper will be based were carried on at the Sparta Experimental Plot near Sparta, Monroe county, Wisconsin ; for this reason a detailed description is given of this area in order that the reader may understand the facts more clearly.

1. Bulletin 204, Wisconsin Experiment Station.

Derivation of Soil on Sparta Field. The Sparta Experimental Plot is located in the La Crosse river valley which consists of rolling and flat river valley lands, chiefly of sandy and sandy loam soils. The uplands lie from 1100 to 1400 feet above the sea level.

The soil in this territory is derived largely from the underlying rock of St. Peter and Potsdam sandstone, all of the material having been reworked by the stream. The St. Peter sandstone is very loose and contributes largely to the lighter soil types of which the field upon which the work is done is typical. This type of soil is somewhat dark in color; and consists of from five to eight inches of loose medium coarse sand, while the subsoil is a loose yellowish or whitish sand similar in texture to the surface soil and extending to a great depth. It is well drained, so much so that it is inclined to be droughty. The unproductiveness of these soils is shown to a large extent by the original growth of scrub oak and jack pine. Sandy soils in other sections of the state are as a rule in better condition, so methods employed in renovating this type of soil would undoubtedly prove beneficial to all sandy soils.

Physical and Chemical Composition. A mechanical analysis which is given below and which was made by the Department of Soils of the United States Department of Agriculture, shows these soils to be low in organic matter, high in silica, and low in its silt and clay content. Organic matter in quite large amounts is necessary to make a productive soil. This question will be taken up later. The presence of a large amount of silica and a small amount of silt and clay indicates further that the soil is low in fertility.

	Organic matter	Gravel sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
		mm. 1--3	mm. 1-0.5	mm. 5-25	mm. 25-.01	mm. 01-05	mm. .05-.005	mm. .005 or less
	%	%	%	%	%	%	%	%
Sand 0 to 24 in.	1.07	0.12	6.14	25.02	55.54	4.16	4.36	3.9
Subsoil 24 to 36 inches.	.34	0.16	8.50	28.96	54.40	3.58	1.86	2.24

A chemical analysis shows still more decidedly the lack of plant food in these soils. The analysis of the soil was made by the writer from a composite sample taken when the field was selected for experimental purpose. The following table gives the percentage and pounds per acre of each element in which a soil may be deficient, comparing sand with an average clay soil.

Element	Sand Per cent	Sand Pounds per acre	Clay Per cent	Clay Pounds per Acre
Phosphoric Acid	.071	1775	0.12	2400
Phosphoric acid soluble in $\frac{N}{5}$ HNO_3	.009	135	----	------
Potassium Oxide (K_2O)	.480	12000	2.05	40000
Nitrogen	.0821	2052	0.14	2800
Calcium	.042	1050	----	----
Carbon dioxide	.016	400	----	----

When comparing the plant food content of the two soils given above, we can readily see that the sands are very much poorer in all elements in which the comparison is made. This type of soil is also low in calcium , so much so, that experiments in which calcium was added showed an increase in plant growth.

The $N/5$ nitric acid determination for available phosphorous shows that the percentage of available phosphorous is lower than .015%[1] the point where soils will respond to phosphorous fertilizers. Actual experiments show that this soil will respond readily to phosphorous as well as other commercial fertilizers.

1. Wisconsin Exp. Sta. Rept. 1908-09 Stoddard, C. W.

Plot Experiments

The Experimental Field is divided into six plots lettered from A to F; each plot being sub-divided into subplots, and numbered. On the south side of the field, plots, A, B and C, are subdivided into eleven subplots each of which being fertilized differently as shown in the diagram. A three year rotation of corn and potatoes, a grain crop, and a leguminous crop, is carried out on this field. On the north side, plots D, E, and F are subdivided into six strips upon each of which a different leguminous crop is grown. The fertilizer is applied on strips runing at right angles to those already mentioned, thus making thirty suplots in each plot as shown on the diagram. A three year rotation is practiced, viz., two years in legumes, and one year a cultivated crop. Of the two rotations the latter has proven itself more efficient in the renovation of these soils as is shown in the following data.

In discussing these rotations we will first consider the one in which a leguminous crop was grown only one year. This soil is so poor that a leguminous crop failed to grow properly during some years, which accounts in cases for irregularities that occur in the data given. The tables below give the yields of corn, corn fodder, and potatoes obtained from three plots, A, B, and C. In 1906,1907 and 1908 no corn was secured. In 1908 no record was obtained of the yield of potatoes.

Yield of Corn for 1909, 1910 and 1911.

Fertilizer applied	1909	1910	1911
Phosphorous, potassium & limestone.	3 bu.	26 bu.	34 bu.
Phosphorous and potassium	4 "	14 "	18 "
No fertilizer	2 "	10 "	4 "
Ground limestone	4 "	15 "	31/2
Peat, phosphorous & potassium.	7 "	29 "	31 bu.
Manure	13 "	25 "	12 "
Phosphorous	6 "	21 "	13 "
No fertilizer	4 "	19 "	2 "
Phosphorous and limestone	3 1/2	18.5"	3 "
Potassium and limestone	5 1/2	18. "	10 "
Potassium	5	14	9 1/2

Yield of Corn Fodder, 1909, 1910 and 1911.

Fertilizer Applied	1909	1910	1911
Phosphorous, Potassium & limestone	2500 lbs.	3350 lbs.	5000 lbs.
Phosphorous & potassium	2550 "	1850 "	2660 "
No fertilizer	2100 "	1760 "	1600 "
Ground limestone	2550 "	2210 "	1350 "
Peat, phosphorous & potassium	4000 "	3150 "	3500 "
Manure	4100 "	5430 "	2560 "
Phosphorous	2700 "	2100 "	2750 "
No fertilizer	2850 "	1900 "	1200 "
Phosphorous and limestone	2950 "	2220 "	1120 "
Potassium and limestone	3000 "	2550 "	2160 "
Potassium	2850 "	3060 "	1920 "

The yields given above are all per acre. In giving the number of bushels of corn, the amount of shelled corn was computed from the corn in the ear, taking seventy-two pounds to the bushel.

Total Yield of Potatoes from 1906 to 1911.

Fertilizers Applied	1906	1907	1909	1910	1911
Phosphorous, Potassium and limestone	58 bu.	60 bu.	32 bu.	55 bu.	100 bu.
Phosphorous and potassium	52 "	54 "	18 "	41 "	78 "
No fertilizer	42 "	38 "	15 "	35 "	31 "
Peat, Phosphorous and potassium	61 "	68 "	24 "	47 "	54 "
Manure	133 "	107 "	23 "	91 "	42 "
Phosphorous	40 "	41 "	9 "	30 "	60 "
No fertilizer	38 "	45 "	16 "	30 "	12 "
Phosphorous & limestone	37 "	44 "	24 "	34 "	
Potassium and limestone	46 "	63 "	25 "	34 "	
Potassium	34 "	56 "	22 "	37 "	

Conclusions. These tables bring out many things which are or seem to be somewhat contradictory. For instance we find an unusually large crop of potatoes during the years 1906 and 1907 while during these years, corn failed to grow almost entirely, thus emphasizing the necessity of more than one test crop. Variations due to season are strikingly shown, thus again emphasizing the need of long time experiments before definite conclusions can be drawn. However, we may arrive at the following conclusions, but further proof is necessary before they can be adopted universally.

1. As a fertilizer from the standpoint of increased yields, manure ranks first; phosphorous, potassium and

limestone second; and peat, phosphorous and potassium, third.

2. Where phosphorous, potassium and limestone was applied we see a gradual increase in yield during the three years; where limestone was applied alone or where no fertilizer was applied there is a decided decrease in yield or in other words, a rapid depletion of fertility.

3. This type of soil is deficient in all elements usually needed and when one or two elements only are added no decided gain is made as seen when phosphorous or potassium was added alone.

4. Limestone when used with other elements as phsophorous and potassium proved beneficial as shown by the two adjoining fields, one fertilized with K, P & Ca, the other with K and P only.

5. In the production of crops, manure proved more efficient on the average than a combination of peat, phosphorous and potassium, but the latter produced the largest yield during the last year (1911) and further experiments may prove it to be equally valuable or more efficient as a fertilizer.

6. While commercial fertilizers have not produced an increase in crops equal in amount to that produced by

manure, yet the results obtained by their use have been such that it is advisable to use them more extensively in the future, especially in localities where manure cannot be obtained readily.

A smaller amount of data is available in the three year rotation consisting of two years in legumes and one year in a cultivated crop. Results can only be given for test crops grown in 1909 and 1911

Yield of Corn&Fodder with Serradella as a
Green Manuring Crop.

Fertilization	Year	Corn	Fodder	
	1909	1911	1909	1911
Manure	8 bu.	75 bu.	1900 lbs.	4680 lbs.
Phos. Potash & Limestone	4 "	42 "	800 "	2764 "
Phos. & Potash	5 "	45 "	760 "	2880 "
No Fertilizer	1.5"	15 "	2000 "	1586 "
Limestone	2 "	13 "	1750 "	1224 "

Yield of Corn & Fodder with Cowpeas as a
Green Manuring Crop.

Manure	12 bu.	34 bu.	2200 lbs.	3024 lbs.
Phos. Potash & Limestone	2.5"	22 "	700 "	1638 "
Phos. & Potash	4.5"	23 "	675 "	1818 "
No Fertilizer	3 "	10 "	1450 "	1080 "
Limextone	2.5"	8 "	1100 "	1026 "

Yield of Corn & Fodder with Lupines as

A Green Manuring Crop.

Fertilization	Year	Corn	Fodder	
	1909	1911	1909	1911
Manure	10 bu.	20 bu.	1000 lbs.	1512 lbs.
Phos. Potash & Limestone	3 "	11 "	650 "	1008 "
Phos. & Potash	4 "	19 "	675 "	1656 "
No Fertilizer	1 "	6 "	1150 "	792 "
Limestone	3.5"	7 "	1100 "	720 "

By comparing the above data with the tables previously given, we find that for the same methods of fertilization, in similar seasons, there is a much greater percentage increase in the latter case, i.e. the second rotation has proven itself superior to the first in the production of crops. It is naturally expected that this should be true, for it takes a longer time and is more expensive to produce the cultivated crop in the latter instance. The question of the increased cost of production in the second rotation is again offset by the fact that the grain crop is usually grown in the first rotation is so poor on many sandy soils that it is practically valueless. When a sandy soil is in fairly good condition, a rotation which yields a reasonable profit besides keeping up the fertility of the soil is the one to be used. This question will be discussed later.

Legumes and Nitrogen.

Sandy soils are especially deficient in humus and nitrogen besides other elements and any method which will increase the humus content of these soils will increase their productive capacity. Green manuring crops increase the amount of organic matter; and different crops have the power of supplying different amounts of organic matter. Legumes also supply nitrogen and are more valueable for this purpose than the ordinary crops such as buckwheat, rye, etc. Even legumes supply varying amounts of humus and nitrogen. For instance, from the tables given above we find that Serradella has produced the largest increase in the yield of corn and fodder, while cowpeas ranks second. This increase in yield is due to the fact that more humus and nitrogen was supplied to the soil by the crop of Serradella plowed under during the previous year. Alfalfa and clover are the most valuable as green manuring crops, but it often occurs that the farmer on these soils is unable to secure a good stand of these legumes and must resort to other methods to place his soil in such a condition that these crops will grow properly. The above tables show that commercial fertilizers combined with annual legumes have increased the crops materially and thus are valuable in the supplying of humus and nitrogen.

Annual legumes such as Serradella, sand vetch, cowpeas, soybeans and lupines have grown successfully on poor sandy soil where other crops have failed, and are very beneficial in improving the condition of these soils. Experiments on the Sparta field has shown that Serradella has proven more efficient in supplying nitrogen and humus than any other legume tried. Sand vetch ranks second, with cowpeas, soybeans and lupines ranking third, fourth and fifth in the order given.

The habit of growth of the Serradella plant is similar to that of clover in that its roots are fine and fibrous, spreading in all directions and making a complete network of roots underneath the surface. Numerous nodules are present when the soil is properly inoculated. The plant above ground is finer than the clover plant, branches are numerous and it blossoms profusely. It is a rank grower during favorable seasons even on poor sandy soils. It has grown to a height of two and one-half feet on the Sparta substation, forming a matting of solid material so thick that it was almost impossible to turn it under with a plow. When turned under it decays more readily than cowpeas or soybeans and does not leave the soil in such a porous condition. It is sure to catch, is quite hardy to frosts, and not very susceptible to drought although very little growth is made in extremely dry weather. Its value as a green manuring crop is equal to that of clover, but where clover can be grown it is more profitable than Serradella as more than one crop can be secured from a single seeding.

Sand vetch is an annual legume which may be planted either in the fall or spring. It is not as sure to catch as Serradella and does not seem to thrive properly on these soils, although wild vetch can be found everywhere. Its habit of growth is similar to that of the pea and like the pea it needs a fairly fertile soil. Its roots are numerous and small; nodules are small but arranged in clusters, thus are seen as large masses which are fastened to slender roots. It grows well on the better types of sandy soil and is an excellent green manuring crop.

Cowpeas and soybeans are about equal in value as green manuring crops. The soybean has the upright habit of growth which makes harvesting easy, but is slightly detrimental in plowing it under. It is more frost resistant than the cowpea and may be sown from the middle of May to the tenth of June. The stalk is coarse and strawy, leaves broad and branches large and numerous. When harvested it has the advantage of ripening its seeds at approximately the same time while the cowpea does not. A surer stand is secured with the cowpea as the seed is not spoiled so easily by overheating in drying. The cowpea also does better when sown broadcast as it is better able to compete with existing weeds. Both of these plants have the objectionable feature of a coarse straw which causes a very open soil when plowed under. The roots are not fine and fibrous as in the case of Serradella and clover, and fail to supply as much humus. The nodules are large and quite numerous being fully as efficient in fixing nitrogen as those of other legumes.

Lupines have done very poorly on this type of sand; its value as a green manuring crop being very small. The plant does not seem to be adapted to the climatic conditions, being injured by small fluctuations in temperature and moisture. Although the leaves are small, the stalk is coarse, ending in a top root with very few smal ler roots branching from it. The nodules of the lupine are usually located on the main root and are quite large and fleshy, but are not very efficient in gathering nitrogen.

Alsike clover, although not an annual has been tried but failed to prove successful. The seed germinates well, but the root system is unable to secure sufficient food for the proper development of the plant and in consequence thereof, the plant dies down gradually. Mammoth and Medium red clover have proven themselves superior to alsike clover.

During the season of 1911 a successful stand of Mammoth clover was secured. The best catch being obtained with a phosphate potash and limestone fertilizer combined with a green manuring crop plowed under in 1909. This stand was secured without a nurse crop. During the season 1912 one crop of clover will be harvested and the second crop plowed under, thus obviating the necessity of losing the crop from the field. We can easily understand from the above illustration that annual legumes combined with commercial fertilizers are invaluable aids in the renovation of sandy soils.

Influence of Tillage. One fact is very noticeable in connection with these legumes as well as with other plants. By placing the leguminous plants in two classes, i.e. those which have been cultivated during the season, and those which have not we find that the average increase of the corn crop is greater where the field was not cultivated even though larger crops were plowed under in this case. In other words, cultivation caused a loss of plant food and humus sufficient in amount to offset the increase in fertility due to the plowing under of the green manuring crop. The following table gives the weight of corn and fodder obtained on fields where the different legumes were plowed under during the previous year.

Uncultivated Crops.

Legume	1909 Corn	1909 Fodder	1911 Corn	1911 Fodder
Crimson Clover	260 lbs.	920 lbs.	----	----
Alfalfa	161 "	860 "	----	-----
Alsike	200 "	860 "	1752 lbs.	1674 lbs.
Serradella	290 "	980 "	3128 "	2519 "
Sand vetch	229 "	905 "	2040 "	2059

Cultivated Crops

Legume	1909 Corn	1909 Fodder	1911 Corn	1911 Fodder
Cowpeas	325 "	1065 lbs.	1552 "	1717 "
Lupines	224 "	830 "	1472 "	1216 "
Soybeans	---	---	1002 "	1681 "

Comparing the above tables we find that in 1909 there was a slightly larger yield in the case of the cultivated crops, but when we take into consideration the fact that no stand whatever of crimson clover, alfalfa and alsike clover was secured during the previous year, while in the case of cowpeas and lupines several tons of material was plowed under we can readily see that cultivation proved very detrimental. The results for 1911 show a gain of seventy per cent in favor of the non-cultivated crops. In this case also more green manuring material was plowed under where the crops were cultivated, ie. cowpeas, soybeans, and lupines as shown in the following table:-

	Green Material plowed under.
Soybeans	9200 lbs.
Cowpeas	9780 "
Lupines	8060 "
Serradella	9000 "
Alsike clover	None
Sand vetch	2300 "

If we compare the individual yields we find that no more green material was turned under in plowing down Serradella than on the soybean and cowpea field, yet the yield of corn on this field was 39 bushels per acre, while on the cowpea field it was only 18.4 bushels per acre. Let us compare the field on which alsike clover and cowpeas were sown. The yield of corn on the alsike clover field was 22 bushels per acre, on the cowpea field 18.4 bushels. No crop of alsike clover was plowed under, but 5 tons of cowpeas was plowed under, still we find a greater yield in the former case. We must hold that cultivation is responsible for this peculiar state of affairs as no other reason can be given.

The question of whether it pays to grow leguminous crops on this type of soil when cultivation is necessary is one needing more attention. The above data tends to show that it does not pay to. The loss in organic matter due to cultivation is sufficient to counterbalance the increase due to the plowing under of the green manuring crop. It is more advisable to grow these crops by sowing in drills six inches apart or broadcast if weeds can be controlled. Sandy soils should not be cultivated too frequently as the losses incurred due to oxidation of organic matter couteracts the benefits derived from cultivation.

Relation of Legumes to Soil Acidity.

The fact that many of the soils of this state are sour or acid due to various reasons is one of importance to the farmer who wishes to till his soil to the best advantage. Sour soils must be sweetened in order to grow legumes successfully and legumes must be grown to secure nitrogen, an element of plant food which all plants need, and which is often present in the soil in very small quantities. The relation that liming and soil acidity bear to the growth of various plants will be taken up in the next few pages. Some instances occur where the calcium content of soils is very lew and experiments carried on by the writer tend to indicate that calcium added to these soils is also used as a plant food in addition to being a soil amendment.

It is a well known fact that liming acid soils for clover and alfalfa is very beneficial, but liming for some of the annual legumes does not seem to produce the same results. Cowpeas for instance seem to be somewhat indifferent to liming. Below are given two tables of the effect of liming cowpeas on the crop itself and corn crop following it.

Effect on Legumes of Liming the Soil

I. Field Experiments.

Cowpeas.

Year	Limed	Unlimed	Remarks
1909	15% better		In favor of liming
1910	4.2 tons	4.3 tons Green Wt.	Same
1911	3.5 "	3.4 " "	Same

Effect on corn crop following cowpeas

Year	Limed		Unlimed	
	Corn	Fodder	Corn	Fodder
1910	400 lbs.	1100 lbs.	500 lbs.	1450 lbs.
1911	648 "	1026 "	792 "	1080 "

The results in the above case show no benefit due to liming, but we must take into consideration the fact that calcium was not the limiting factor, ie. other plant food was needed more than calcium, so the results are not as reliable as they should be. It certainly shows strikingly the fact that liming will not benefit a worn out soil.

In comparison with cowpeas we have soy beans which are very materially benefited by the addition of lime only, as the following tables will show.

	Soybeans		Effect on Corn Crop			
Year	Limed	Unlimed	Limed		Unlimed	
			Corn	Fodder	Corn	Fodder
1910	5.5tons (Gr. Wt.)	3.1 tons				
				lbs.		lbs.
1911	7.0 "	2.7 "	13.8 bu.	1548	11 bu.	1260

We can readily see the beneficial effect of liming on soybeans increasing the crop to the amount of four tons in one season, a very considerable quantity. Its effect on the corn crop following is not so pronounced but further results will bring out these facts more fully.

Lupines.

The lupine, another annual legume judging from results obtained so far is injured by liming. Other Stations where lupines have been grown show the same results.

Season	Limed	Unlimed.
1910	1.7 ton Green Wt.	2.9 ton
1911	.9 " " "	2.2 "

We can conclude from the above data that liming for lupines is not beneficial from the standpoint of soil acidity.

Serradella and Sand Vetch.

Very little definite data is at hand in regard to the relation of serradella and sand vetch to liming. In 1910 and 1911 serradella grew as well on the limed as on the unlimed field while no difference was noticeable in the corn crop following it. Sand vetch was about 75% better on the limed field in 1910 while in 1911 a crop of 1740 pounds was secured on the limed field while only 220 pounds were obtained on the unlimed. The corn crop following vetch was also better in the former case

II. Experiments in the Plant House in Liming

In order to show the effect of different amounts of calcium carbonate on plant growth with this type of soil (Sparta sand) an experiment was planned as follows. Seven jars were nearly filled with soil taken from an unfertilized field at Sparta. The first jar, or jar number one, r eceived no treatment; jar number two received an pliaation of chemically pure calcium carbonate equivalent in amount to an application of five hundred pounds per acre; jar number three, one thousand pounds per acre; jar number four, two thousand, and so on, the last one having five thousand pounds per acre. The calcium carbonate was thoroughly incorporated into the top six inches. The test crops used were soybeans and corn.

The results obtained show that liming was decidedly beneficial. The maximum growth was produced on the jars which received applications of two and three thousand pounds per acre as shown in the pictures. There was a gradual increase in size of plants in jars up to three thousand pounds in the case of corn, and two thousand pounds in the case of soybeans. The following table gives the percentage of nitrogen, calcium and magnesium in the soybean plants in each of the jars.

Jar Number	Wt of Plant grams	Per cent N.	Percent Ca.	Per cent Mg.
1	0	--	--	--
2.	6.0712	7.7	1.6	.280
3.	8.8280	7.8	2.17	.375
4.	17.8940	7.87	2.11	.285
5.	14.0869	6.34	2.68	.205
6.	5.6452	7.12	2.69	.290
7.	---	---	---	---

Grams per Plant of Nitrogen, Calcium & Magnesium

Jar No.	Nitrogen	Calcium	Magnesium
1.	--	---	---
2.	.467	.1034	.017
3.	.694	.1915	.033
4.	1.395	.3769	.051
5.	.893	.3775	.029
6.	.402	.1512	.016
7.	---	---	---

From the above data the following conclusions can be drawn.

1. The nitrogen content was not increased percentagely, but there was a gradual increase in the number of grams of nitrogen until jar number four when a decrease is again noticeable.

2. The calcium content of the plants increased percentagely but the number of grams of calcium, due to the poor growth of the plants in jar number six, was very small or less than the others.

3. The percentage of magnesium was variable, but the largest number of grams of magnesium is found in jar number four where maximum growth was reached.

4. An application if five thousand pounds of calcium carbonate proved injurious in both cases. Plants also did not grow where no lime was applied. What the increase in growth is due to is still undetermined. The increase in the number of grams of nitrogen would indicate that more nitrogen was liberated by the application of correspondingly larger amounts of calcium carbonate. If this were true entirely, it would also stand to reason that jar number seven should have the largest growth instead of none at all. Soybeans need a large amount of calcium which is shown by field tests spoken of earlier in this paper.

In looking over the table we find that the calcium content of the plants increased percentagely, which would tend to indicate that the more calcium added, the greater the growth. An analysis of the soybean plant which grew on non-acid-soil, indicates the calcim content to be 1.91% We see that some of the percentages given in the above table are higher and some are lower which would again mean that more calcium must be present in these soils for normal growth.

The experiment was repeated using corn as a test crop and similar results were obtained. In conclusion, we may say that the cause of these results is still unknown, and more work on this subject is necessary.

Blowing of Sandy Soils by Wind.

The problem of blowing of sand by wind is a very serious one, needing more attention than is ordinarily given to it. Sandstorms which are equal in severity to snowstorms are not uncommon, in the early spring and late fall months when most of the field is exposed to the action of the wind. Banks of sand two or three feet high are not infrequently seen along fences, hedges, brush piles, etc. in sandy regions.

This movement of sand often causes great damage, not only to the soil itself, but also to crops growing on the soil. If we examine a bank of windblown sand very closely, it appears to be nothing but a mass of small particles of silica which have no fertility whatever. This is very true. A chemical analysis of this soil by the writer shows it to be very poor in plant food elements, in fact so small that the amounts are inappreciable. The analysis shows the following:- P_2O_5, trace; K_2O, .023%; nitrogen, .015%. When a sand bank is formed though, only the largest particles as a rule settle and the finer particles which carry more fertility are deposited after traveling greater distances. That this movement does occur can be shown by the dust that collects on snow banks in winter, or by the dirty appearance of standing water. Another factor to be taken into consideration is that the soil is being constantly removed and if the process continues a long time the surface layers disappear, leaving only the more unfertile subsoil which is deficient in available plant food. However important this may be, more damage is done by the injury to young and tender plants by blowing sand. This is done in two ways, by covering the plants, and by producing a mechanical injury or in some cases, by cutting off the young shoot entirely. The drying of plants due to the increased velocity of the wind on level fields is also a factor in the handling of soils of this type. During the springs of 1909 and 1910 on the Sparta Substation, fields of cowpeas and soybeans were injured so severely that very few plants grew . In 1911 a field of oats was injured so severely that one-fourth of it was plowed and replanted. At no time during the six years work on this station did crops escape injury entirely.

Several ways for the prevention of blowing sands are now in use, but some are ineffective and others are too expensive or require a longer time to place them in operation. Two methods only, will be discussed in this paper. They consist of decreasing the exposure, and changing the texture of the soil. The exposure may be decreased by a covering of vegetation, by leaving stubble fields, by planting or leaving natural windbreaks and by a covering of straw or manure. Roughing the field by means of a drag or corrugated roller has been very beneficial in many cases, due to the fact that the velocity of the wind is decreased and finer soil particles often lodge in the depressions. The texture may be modified by the addition of organic matter in the form of manure, peat and green manures; by the addition of clay, and by liming.

Windbreaks which are often used, may be made of hedges of evergreen or other trees on the edge of the field. These are quite expensive and require time to build, but are very effective as a means of preventing damage. Natural windbreaks, i.e. in which several rows of trees are left around each field when the land is cleared are the most effective in the protection of this type of soil, and are now used extensively where sandy land is being cleared.

The growing of a crop of fall rye, vetch, clover, etc. which covers the ground in the early spring and late fall is a practice which deserves more attention than is ordinarily given to it. The method of planning the rotation so that narrow strips are available in which a bare strip and one with a cover crop can be alternated is very commendable. In this rotation even if blowing does occur the particles as a rule will remain on the field. The presence of grain or corn stubble has been a very effective means of preventing losses.

Straw or manure when applied to a sandy soil could be spread over the surface in the fall and allowed to rot as well as prevent blowing. When plowed under, these substances furnish humus which in turn increases the water-holding capacity, both factors causing a more thorough binding of soil particles. The humus and moisture content are also increased by the use of green manures some of which have been discussed previously.

Peat when decomposed has been found to have a very decided effect on the binding of soil particles due to the organic matter which it adds. Its use is becoming more and more prominent not only for its value in furnishing humus, but nitrogen as well. Claying sandy soils is sometimes practiced for the purpose of binding them together. It is a very expensive method as large quantities of clay must be used and the amount of labor involved almost prevent its being used.

Systems of Farming for Sandy Soils.

Many systems of farming are being used on the poor sandy lands of the state, but very few of them have proven successful to any appreciable degree. General grain farming is unprofitable. Livestock farming is practiced to a large extent, and at first thought would seem to be the best adapted to this type of soil. This however, is not always true, and in some sections we find the strictly livestock farmer unable to make a comfortable living. The farmer who has a diversified means of sustenance is the one who is most successful, by this is meant the farmer who does not depend on any particular line of farming for his profits.

The reason for the unprofitableness of grain farming are very obvious. A few words on this subject will suffice. The fertility of these soils is very low and grains , if grown continually, or in rotation will soon deplete the soil. Furthermore if the crops obtained are not lare enough to enable the farmer to purchase commercial fertilizers at a profit, he soon finds himself poorer than when he first began. This is true with grain farming.

Livestock farming is successful on the better sandy and sandy loam soils, sometimes alson on the poorer sands, but much depends on the ingenuity of the farmer. Livestock farming combined with the growing of special crops is the most profitable line to follow as will be shown later. The advantages of livestock farming are,

1. It tends to keep up the fertility of the soil more than any other kind of farming.

2. It is profitable to a certain degree.

3. It would stop many of the losses which occur on sandy soils through windblowing, leaching, etc.

The disadvantages are:-

1. It is difficult to raise sufficient feed to keep a large number of animals.

2. The return of manure to the field is not sufficient to maintain the phosphorous and nitrogen content.

3. The net profit is not sufficient to warrant the purchase of commercial fertilizers as well as food-stuffs. A large area of land is usually needed to supply sufficient feed and the tendency seems to be to rob one part of the farm to maintain the fertility on the other part.

Farmers who are located in the sandy sections of the state, if successful, have resorted to a system of general farming for their profits. It is true that livestock farming is one of the means of attaining that success; but is only made possible by the fact that special crops such as vegetables, strawberries or other small fruits, cucumbers, beans, etc. have furnished a revenue which tided them over in times when crops as a rule failed and feed ran low. These crops furnished the money for the purchase of additional feeding stuffs to keep the stock alive during the winter months. Failures in hay and pasture are not infrequent, but as a rule the corn crop can be depended on year after year. We must look at this question from the fertility standpoint if such practice is to be continued for any length of time. Dr. C. G. Hopkins in his book on Soil Fertility and Permanent Agriculture, makes the following statement. "Even under the best system of independent livestock farming, i.e. without the dependence on the purchase of supplementary foodstuffs or the use of manure from town, it is necessary to purchase some phosphorous in order to replace that which is sold in the animal and animal products." The above statement applies especially to clay soils. Sandy soils also need potassium as is shown by the analysis given previously. Thus we see that potassium as well as phosphorous must be purchased in the form of commercial fertilizers, while nitrogen must be obtained from legumes. No definite data can be given in regard to the maintenance of fertility but the losses of nitrogen through oxidation and leaching are very large.

Systems of rotation cannot be planned which can be applied rigidly to these soils as conditions are variable, but leguminous crops should occupy a prominent place in all rotations. A good rotation should embody the following points.

1. It must furnish green manuring material as well as nitrogen.

2. It must provide protection from wind and the loss due to leaching.

3. It must produce sufficient feed for animals at all seasons of the year.

4. It must provide for the selling of some crop which will enable the farmer to purchase fertilizers.

5. It must increase the water-holding capacity of soil.

A rotation consisting of two years in legumes and one year in a cultivated crop should be used on the very poor sandy soils where it is impossible to grow any crop successfully without the addition of manure or commercial fertilizers. In addition to the growing of legumes 300 pounds of acid phosphate and 200 pounds of sulphate of potash should be supplied once every three years to increase the fertility of the soil. This method is somewhat expensive but its cost should be added to the initial cost of the land. When the land is in better condition this rotation may be changed to one having a year in cultivated crops and a year in annual legumes, and later to a four year rotation with a grain crop, cultivated crop and two or three years in clover or alfalfa. The land at this time should be in such condition that clover and alfalfa should start readily. If manure is available it should be applied on the cultivated crop while commercial fertilizers should be applied to the leguminous crop. Manure is not lost as readily as commercial fertilizers and would help materially to increase the profits of the cultivated crop. As many leguminous crops as possible should be plowed under, depending on the income of the farmer. The kind of legume to be used has been discussed previously. If possible, cowpeas and soybeans should be sown in with corn and remain as a winter cover crop; or rye may be sown at the last cultivation of corn for the same purpose. Rye and vetch sown in the fall often make a good combination for hay and should be used as much as possible. Inoculation and proper methods of culture will play an important part in the success of these rotations. Livestock farming should also be carried on in conjunction with the above rotations to the actual extent that feed may be obtained for it.

Aside from the fact that livestock farming combined with the growing of special crops is successful, there is still another line which has proven successful to a large extent, especially for the man who has little capital. This is fruit farming and vegetable growing. These soils present advantages for this work which cannot be overlooked.

They are as follows:-

1. They are early and easily cultivated.

2. They are well drained and aerated.

3. They respond quickly to fertilizers.

4. They are adapted to the growing of small fruits and vegetables.

5. The crops are sufficiently profitable to enable the farmer to purchase commercial fertilizers.

This land as a rule is purchased cheaply and some money could be spent in the buying of fertilizers. Then a cultivated crop such as strawberries, raspberries, etc. could be planted. In many cases green manuring crops can be planted between the rows thus furnishing humus. Beans, watermelons, cantaloupes, etc. form a ready source of revenue for the small farmer. But the man who does this kind of farming must also remember that green manuring crops are necessary for success. Poultry farming to the man so inclined could be carried on profitably with the above system . Additional profit would thus result at a small expense.

The effect of varying amounts of lime on poor sandy soil is shown in the above picture. Maximum growth was produced by an application of lime at the rate of three thousand pounds per acre.

The above picture shows the effect of increasing amounts of lime on soy-beans. Maximum growth was produced by an application of lime at the rate of two thousand pounds per acre.

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Prof. of Soils