# CHANGES THAT TAKE PLACE IN THE SOIL.

By C. O. Williams, Chemist, Government School of Agriculture, Cedara.

The soil, metaphorically speaking, is the foundation of Agriculture, and the choice of land and the care of the soil should be looked upon by the farmer as the most essential factor for success. For this reason I do not offer any apology for bringing up again this subject before the Sugar Congress, dealing with it from another point of view. The more one studies the soil the more one realises that there is still a lot to learn about it, and the more important the subject of the maintenance and improvement of the soil fertility becomes.

In this short paper I only propose to deal very superficially with a few points in the hope that some of you will give us your views on, and practical experience with, this problem of building up the fertility of the soil, and that it will lead to a useful discussion.

In the first place, one does not perhaps realise that the soil on a certain piece of ground is for ever changing. When a farmer says that he has been cultivating a particular bit of soil for the last 40 or 50 years he is far from being correct. In the course of that interval of time the top few inches may have entirely disappeared, with the slow, continuous formation of fresh soil underneath from the subsoil. Even that portion of the original surface soil that has not been completely removed slowly undergoes changes in character and composition. Let us inquire a little more closely how some of these changes are brought about:—

(a) The weather agencies (rains, wind, etc.), carry away bodily the loose material from the surface, and this would ultimately find its way into streams to be either deposited by them in the low-lying valleys or carried out to the sea, to be deposited in the ocean flow as the first stage in the formation of future rocks. It is obvious that it is the lighter and finer particles that are removed in this way, and this is the richer and most valuable portion of the soil for various reasons: (1) the fine material holds the moisture in the soil far better than the course particles; (2) the finer mineral matter in the surface soil has undergone a greater change from the original, undecomposed state than the coarser material, and for that reason it contains the plant food in a more soluble or available form; (3) the lighter material consists very largely of humus, which besides being the source of nitrogen and other fertilising constituents in the soil has also a marked beneficial effect on the physical properties of the soil; and (4) it favours the retention of the soluble salts and this prevents them from being washed down through the subsoil and drained away.

Instead of actually washing away the fine particles of the surface the rain may wash them down through the soil into the subsoil. For this reason the subsoil is usually more clayey and compact than the surface soil.

For the above reasons it is very important that this fine, partially-decomposed material in the surface soil should be conserved as much as possible. The erosion may be prevented or minimised in many ways: (1) By covering the ground with a crop or a vegetable mulch as much as possible; (2) by ploughing and planting crops along the contour; (3) by a system of ditches or open furrows with only a slight fall, and (4) by terracing, so as to diminish the slope of the cultivated area.

It need hardly be mentioned that the conditions largely prevailing on the coast of Natal,—steep hillsides with light, sandy soils,—are the very worst for erosion.

(b). The rain falling on the surface of the soil washes down also the soluble saline matter into the subsoil and finally into the natural underground drainage system, so that it is finally lost altogether. Certain constituents are washed down more readily than others. For example: phosphates, potash and ammonia are not lost to any great extent by percolation, but the carbonates, sulphates, chlorides and nitrates of lime, magnesia and soda are very readily lost. For the reason, the practice of adding nitrate of soda as a top dressing, but sulphate of ammonia during time of planting is understood.

Again, the loss of carbonate of lime in the soluble form by percolation shows the need for supplying this material to the soil from time to time. Sulphates are fairly readily lost by percolation, but this constituent is always added to the soil when ordinary superphosphate is used as a fertiliser, for the latter is really a mixture of a water soluble phosphate of lime and sulphate of lime. Should it be suspected, therefore, that sulphates are required for a particular soil in addition to phosphates then a very useful fertiliser would be superphosphate. Sulphate could also be applied along with potash in the form of sulphate of potash, or with ammonia in the form of sulphate of ammonia. Sulphate could also be applied in the form of gypsum (sulphate of lime) but it is very seldom that there is any need for the addition of a sulphate to a soil.

Another substance easily lost from the soil by percolation is sodium chloride (common salt) and chlorides in general, but it is not often that it is found necessary to add chlorides for manurial purposes to the soil. Certain sugar soils from the coast

were analysed in our laboratory recently, and it was found that although a fair amount of chlorides were present in the surface soil, the proportion in the subsoil (the second 9 inches) was very small indeed. This marked difference could perhaps be explained by the fact that the sea spray is often carried mechanically by the strong winds for several miles inland, in minute amounts, and this would be continually falling on the surface of the soils in that zone. It is possible, however, that this continuous, though small, addition of sodium chloride to the surface soil may not be enough for the needs of such a vigorous crop as sugar cane, which is particularly a lover of this constituent, and for that reason a few experiment plots have been laid down by the Director of the Sugar Experiment Station to test this point.

To counteract this downward movement of soluble material by percolation there is an upward movement of water by capillarity, after the rain has ceased, so that any saline matter in the subsoil is brought up to the surface soil.

(c) Chemical changes are brought about in the soil by the action of such gases as oxygen and carbon dioxide (carbonic acid gas) from the air, and by such acids as carbonic acid and various organic acids either excreted from the roots of plants or produced during the decomposition of organic matter. In this way the rock material of the soil is gradually broken down and the minerals composing it are decomposed, so that the constituents become more soluble. The action of the above-mentioned gases would obviously be stronger in the cases where the soil is porous and is not waterlogged, for otherwise there is not much chance for these gases from the atmosphere to penetrate the soil. It should also be borne in mind that certain poisonous substances in the soil can be oxidised to produce harmless or even beneficial compounds if the soil is sufficiently aerated to ensure a good supply of oxygen in its pores. Thorough tillage and good drainage will specially assist in the these cases.

(d) Chemical changes are also brought about by the various organisms in the soil. A thimbleful of ordinary fertile soil may contain many millions of these organisms (chiefly bacteria and protozoa), and although microscopic in size in the aggregate they bring about enormous changes in the soil. Some species of organisms can act on the mineral matter of the soil and decompose it, but most of them confine their activities to the organic matter in the soil. Different organisms bring about different chemical changes in this organic matter. For examples, certain species of bacteria will attach the nitrogen of the proteins and produce ammonia, but other species will ultimately convert this ammonia into nitrates. The other elements in the various organic compounds (chiefly carbon, hydrogen and oxygen) will first of all be converted in such compounds as the alcohols, various organic acids, etc., and forms of humus, but in a well aerated soil all these substances will ultimately be oxidised to carbonic acid gas and water. It is thus seen that the organic matter of the soil constantly disappears and means have to be adopted to keep up the supply. Of course, under natural conditions this is done automatically, but in modern systems of farming, involving the removal of stock and crops, special means have to be adopted to maintain or increase the proportion of organic matter in the soil. If the soil is not sufficiently aerated and is more or less waterlogged, the beneficial organisms cannot thrive and the above-mentioned changes do not proceed to the ultimate stages as they should. In fact, various acids and poisonous substances would accumulate, and the fertility of the soil would be seriously lessened. Hence again the importance of drainage and thorough cultivation.

### Acidity.

In connection with this subject of accumulation of acidity in the soil it may be mentioned that there are various causes of sources of acidity in the soil, they may, however, be roughly divided into inorganic (or mineral) and organic causes. There are produced, for instance, during the decomposition of the rock material in some soils certain compounds which have an acid reaction, and it is these that chiefly produce what one may call mineral acidity in the soil. On the other hand, as explained above, in a certain stage of the decomposition of organic matter by the soil organisms various organic acids are produced, but if this soil is well aerated the organic acids rapidly get oxidised. It is often considered a mistake to add a lot of organic matter to the soil because in that way you would increase the acidity unduly, but as previously stated if you keep the soil well drained and prevent any tendency to waterlogging there is not much fear of an undue accumulation of organic acids in the soil. It is, however, sometimes noticed that crops do badly for a short while on a soil to which great additions of organic matter have recently been made. This may be due to various causes: (1) Temporary accumulation of acidity; (2) the denitrifying bacteria are very active under such circumstances, so that some of the nitrogen escapes in the elementary form into the atmosphere; (3) the large amount of organic matter conduces to a very marked increase in the total number and vigour of the bacterial organisms, which deplete the soil of its available nitrogen in order to build up their own bodies and the crops in consequence suffer temporarily from nitrogen starvation.

Certain experiments have been carried out in the laboratory at Cedara during the past few years which throw a good light on the effect produced on the soil by the addition of organic matter. Portions of the local soil were placed in several glass cylinders fitted with an outlet at the bottom to ensure free drainage. In certain of these cylinders enough organic matter in the form of chopped hay was added as to double the original percentage of organic

matter in the soil. Every few days enough water was poured on the surface of the soil in each cylinder so as to ensure the soil being kept moist without any appreciable loss taking place by percolation; the soils, on the other hand, were not in a water-logged condition for there was free drainage through the tap at the bottom. At the end of six months the addition of water was stopped and the soil was kept in the cylinders for further period of three months, and then analysed.

One of the interesting conclusions deduced from this investigation was that the portions of soil which received the large additions of organic matter were really appreciably less acid than the soil that receveived no such treatment, and had also a much larger proportion of carbonate present. It seemed as if the carbon dioxide produced during the decomposition of the organic matter had combined with the lime and other similar constituents of the soil to produce carbonate of lime, etc. This investigation completely bears out the statement previously mentioned, viz., that there will be no accumulation of acidity in the soil due to organic mater, as long as the soil is properly cultivated and drained.

In conclusion, it may be stated that the problem of liming is bound up very largely with the question of acidity, but I do not propose to enter any further to-day into it beyond mentioning that the question of liming in this country is not so simple as it is in the temperate countries of Europe. No farmer should spend money on lime until he has proved by experiment that it is necessary on his own lands.

## DISCUSSION ON THE CHANGES THAT TAKE PLACE IN THE SOIL.

Mr. C. J. Rapson asked Mr. Williams if he could tell him what effect the eel worm had on the soil after applying green manuring crops. If a crop of cow peas was put in he sometimes found a heavy infestation of eel worm. This of course disappeared after ploughing. He wished to know if the worm had any detrimental effect on the soil. Secondly he wished to know what action took place in the soil after a crop of say buckwheat had been applied and turned in to the soil. During the last season he had applied buckwheat and he had had the soil analysed before and after the application. It had been found that the soil after the application had brought into available form the potash and phosphates and nitrates that were not in an available form previously. He wished to know how the process was brought about.

Mr. Williams in reply stated that with regard to the eel worm he was afraid he did not know sufficient about its habits to give a reply. He could only reply in a general way as to the effect animals of such a nature had on the soil. There was no doubt that they did open up the soil. That also applied very largely, as they all knew, to the earth worm. If a soil was at all inclined to be clayey in nature the very fact that the worms penetrated the soil and the soil matter passed through their bodies and was brought to the surface, did a tremendous amount of good. He could not say, however, what the particular result was in regard to the eel worm.

Referring to the question as to a crop of cow peas or any other green manuring crop on the soil, that had several effects. First of all it added organic matter; also the plant food that is in the soil is taken up to a large extent by the roots of the green crop. That was ploughed in to the surface soil. If that was ploughed in at the proper stage they obtained the necessary amount of moisture, the crop decomposed very quickly and the mineral matter gathered by the crop during the time it was growing was left in the surface soil in a very readily available form for the crop after.

Mr. Staples stated that the eel worm was a very bad pest on most Natal crops but fortunately it did not attack grass. It did not affect the soil, but was a parasite on the roots of a large number of crops with the exception of grass.

If a crop of cane was growing there would be no effect on the plant, but if it was a crop of potatoes or another crop of cow peas then it would have considerable effect.

Mr. Townsend in referring to Mr. Williams' remarks on the chemical changes in the soil due to tillage, stated that he considered this had a most important bearing on agriculture. He asked Mr. Williams to extend his remarks on that point as to really what chemical change took place. For instance if one was to plough up a virgin field and let it lie with all the growth in it for say two months and then re-plough and harrowed it down, what chemical change would take place? No doubt it was difficult to say without analysis, but he wished to know whether it would be advisable to go further and give it a third ploughing. There appeared to be a great diversity of opinion on the point. Many people held that they could plough three or four times with beneficial results, but when asked to prove it, they simply said "they think so, it must be so, because you turn the soil over." In his opinion if the soil was turned over too often it was more likely to disturb and destroy the bacteria forming in the soil and do more harm than good. He might be mistaken in his opinion, and that was the reason for his asking the question. He wished to know whether a repeated ploughing say within six months was beneficial to the soil.

Mr. Williams replied that of course he could not give a definite answer to the question. It depended

on the soil and on the climatic conditions. With regard to the changes in the soil, first of all the action of ploughing up the land opened up the soil; it gave more room for the various gases that he had spoken about, especially the entry of the oxygen into the pores of the soil, and the chemical changes that brought about the action of rendering soluble unavailable plant food. There may be potash present, combined with other elements in compounds in the soil that are insoluble, but if acted upon by various gases in conjunction with moisture, the potash was changed into a soluble form. The same thing applied to phosphates. With regard to organic matter he had dealt with that fairly fully. Whether three or four ploughings were better than one depended on the circumstances. They did not only want changes to take place in the soil chemically, they also wanted physical changes to take place. They required a proper tilth as well as soluble plant food; with some soils tilth was obtained much easier than with others. From a chemical point of view he could see no harm in repeated ploughings, but on the other hand if the soil was opened up too much, and, the soil was inclined to be sandy, the few inches of soil at the top were deprived of moisture unless it was during the rainy season, and they did not get the changes taking place in the organic matter that ought to take place.

Mr. Edelman agreed with what Mr. Williams had said. There were certain types of soils which could be overdone but with a medium or heavy soil, he did not think there was much fear of overworking them.

Mr. Townsend then referred to the question of erosion. That was another very serious aspect so far as the farmer was concerned, especially in the early stages of cultivation. He asked if Mr. Williams had any suggestions to make to the planters as to the means to be adopted to prevent erosion. He had his own ideas on the subject and would like to hear other opinions. Perhaps it was hardly fair to ask Mr. Williams to tell them what to do, as they should know it themselves. He would appreciate it, however, if Mr. Williams could make any suggestions to them.

Mr. Williams replied that he had mentioned three or four general practices that might assist. He had done so for the sake of encouraging discussion among planters at the Congress and he did not think he ought to say more on that point. He wanted to hear what the planters had done and what they thought ought to be done.

Mr. Rapson stated that he thought cane was different from other crops in that regard. The cane root system was such a vast system and spread to such an extent that once the cane was established soil erosion was not such a tremendous factor in the Coast as it probably was with the lighter growing crops up-country. He agreed with Mr. Williams that the cane should be planted as much as possible following the contour of the hills. That stopped the rush of water before the cane had been established. But after a field had been established, and specially after a crop had been reaped and there were large quantities of trash on it, erosion should not take place. Under those conditions he did not thing soil erosion should be such a serious factor with the cane planter, provided he had used commonsense and reason in the first place.

Mr. Townsend replied that he was sorry he could not agree with Mr. Rapson. He could give them an illustration where a planter woke up one morning and found not only his cane gone, but his fertiliser also. He also knew of a case of three re-plantings through heavy rains. It was a very serious factor that they had to deal with. He had his own methods of dealing with it and he was probably a bit old-fashioned in his ways, but from practical experience he thought his ideas were fairly sound. In dealing with slopes he stated that no matter how keen a person may be about putting his lines on the contour very few followed it entirely.

Another drawback, which assisted erosion, was that they all furrowed. If a heavy rain was experienced the water flowed down the lines and carried away the soil. Little rivers were formed and eventually they carried almost everything away.

Mr. Townsend then proceeded to illustrate on the blackboard how he carried out the work on his farm. He explained that he had a channel system; at every fifteen paces he had a channel. He considered it would take a very heavy rain to wash the channel away. The soil would carry the moisture if it had time. By having furrows running at an angle down the hill it caught the water which escaped and there was not much loss of cane; it acted as a drain. It was really coming back to the old system of holing the land, but instead of having them every yard he hard them every fifteen paces. After the cane was properly established these holes were automatically taken out.

Mr. Rapson asked how the channels were constructed.

Mr. Townsend replied that the soil was simply dug out from the lines alongside of the cane. Little pockets were formed into which the water ran, and by the time the pocket was full the probability was that the rain had gone off and there was very little erosion.

Mr. Hibberd asked what the effect was on the side drains in a heavy rain, to which Mr. Townsend replied that there was very little water running down if the channel system was properly carried out.

Mr. Hibberd asked what was the nature of the soil Mr. Townsend referred to.

Mr. Townsend replied that it applied to any soil really, but light soil for preference. It applied just the same to sandy soil. He had a heavy alluvial soil. The heavy soil was rather bad because it did not absorb the moisture and he had found these drains very effective. Before adopting the method he had had fields washed completely away, but since then he had had very little loss.

Mr. Hibberd asked Mr. Williams what his opinion was as to the results of heavy steam ploughing. He thought that a steam plough went deeper than it should do. He had noticed some planters ploughing out old cane with a steam plough and giving it one

ploughing. He considered that by so doing the best soil was turned in.

Mr. Williams replied that in some soils—some sandy soils, and some alluvial soils—there was very little difference in the extent and composition of the soil for several feet. Deep ploughing would not do much harm in their case, but there were certain other soils with very shallow surface soils, in which deep ploughing would bring up the subsoil to the surface. That was bad for more than one reason. One was that very often it was too loamy and gravelly, and at other times it was too clayey, and by bringing that up to the surface it did not do the surface soil any good; it did not improve the tilth. Another thing was that in the subsoil the plant food was not in an available soluble form probably. The soluble form was ploughed down to the depth of a foot or so and the other soil was brought up in which the amount of available food was not so great. Another reason was that they very often in the subsoil there were poisonous compounds—compounds of iron— due to the lack of oxidisation. When that was brought up to the surface it rendered the soil more or less unfertile. It all depended on the depth of soil as to whether deep ploughing was beneficial or not.

Mr. Hibberd asked if having ploughed up that soil, Mr. Williams could give them any idea of the length of time it would have to remain fallow to become fertile.

Mr. Williams replied that after two or three years the soil recovered its fertility almost entirely.

Mr. Hibbered asked if a fair crop could be expected for the start and that it would improve after the first crop.

Mr. Williams replied that it would improve later.

Mr. H. O. Andrews asked why it was that some soils on the Coast, which were very sandy, but had been heavily timbered in the past, appeared to be exhausted in a very short time. He thought that was the experience of a good many people. Having carried heavy timber one would naturally expect it to be full of humus.

Mr. Williams stated that as a rule the soils on the Coast were very sandy, but porous. The organic matter that was in these soils became oxidised very rapidly. The organisms worked very rapidly—more so than in a stiff clay soil, and the humus was changed as he had explained before into carbon dioxide and moisture and there was nothing left; also the plant food accumulated in the surface soil which was not absorbed by the growing crop was very speedily washed down by percolation into the underground drainage. In that way the soil was speedily impoverished unless by proper cultivation and fertilisation its fertility was maintained, the addition of humus and fertilisers would be the main requirements for such soil, as it would be very easily turned over and cultivated, and as he had said too much of that could be done with a soil of that nature.

# THE PLOUGH, ITS DRAFT PRINCIPLES UNDERLYING ITS USE, ETC.

By B. P. AIRD, Engineer, School of Agriculture, Cedara.

Mr. P. B. Aird, Engineer, School of Agriculture, Cedara, then addressed the members on the subject of "THE PLOUGH; ITS DRAFT, PRICIPLES UNDERLYING ITS USE, ETC," as follows:—

"I intended to say the plow was the foundation of success in connection with agriculture but Mr. Williams has taken the wind out of my sails now (laughter). However, I want to point out to you several little things that we all know but do not usually carry out in connection with that implement known as the plow. We do not give it the consideration that it deserves. Before doing that I wish to take the opportunity of accepting the invitation of Mr. Townsend to visit his farm. I would like to get to "Compensation." What he has mentioned is the type of soil erosion pockets that they use in several of the rubber estates. They make pockets between the trees about every eight feet. I think they are four feet deep and 2 feet wide and they collect the soil and stop the loss.

Now in connection with the plow there are several points that we often overlook. I am not speaking now of steam plowing of which I know nothing. As a matter of fact I don't know much about the other kind of plowing; it is too much hard work and being a Civil servant I am not very fond of it! (Laughter). The principal point I would like to draw your notice to is in connection with the hitch of the plow. Afterwards, with acknowledgments to Dr. Cleghorn of Potchefstroom, I would like to draw to your notice the desirability or advisability of using wider yokes in South Africa. I usually ask the farmer if he has a plow handy on the farm and he invariably says "yes," and turns out one with apologies. Rather than ask a sugar planter to-day I went to Geo. North's, because the last one I had was rather rickety—all the