

# RECENT VIEWS ON SOIL FERTILITY

T. EDEN

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During the hundred years of scientific agricultural investigation there have been, broadly speaking, three phases in soil work. The first from 1830 to about 1870 coincided with increased interest and skill in chemistry, particularly as regards accurate analytical work. This was the period of Boussingault in Alsace, the originator of agricultural experimentation, and of Lawes and Gilbert, the giants of the period who concentrated on the nutrient problem and viewed it chemically. The second phase may be said to have developed out of Louis

Pasteur's researches, though it was some fifteen to twenty years before the avenue he opened became a highway. This period was the micro-organism period, and in it the explanation of leguminous nodules was discovered. Processes in the soil which had hitherto been regarded as merely chemical were found to be the result of the activities of micro-organisms. Soil became the 'living' soil and the biological aspect of soil science was stressed. This period lasted until about the time of the First World War. It has been succeeded by the present one,

the 'soil structure' period. In using the word succeeded it is not implied that the periods superseded each other but were superimposed, the later on the previous. The soil structure emphasis now apparent in soil work is firmly linked with both the chemistry and the microbiology of the soil. The conceptions of soil structure emerged from two different kinds of investigation. They were prompted by the age-long mystery of what exactly 'tilth' in a soil is, and they received added interest from the contributions of the less practical science of pedology, which studies the condition of soil *in situ* and in relation to the soil formative processes through which it has passed.

Present-day views on tilth stress its relationship to the manner in which the individual soil particles are grouped together into more or less stable aggregates, or, more simply, crumbs. In the absence of crumbs a soil is intractable to cultivate and infertile. The crumb structure provides the best conditions for all the activities, chemical, physical (such as water retention and movement) and biological which are necessary for maintenance of fertility. In fact the view is now frequently stated that improvement in soil fertility is attributable more to improvement in the physical than in the chemical constitution of the soil. Fertility is not a simple soil question: it is a soil and root problem. By altering the structure of the soil, the structure, penetration and volume of roots is also modified and the range of exploration and exploitation increased. The chemical, physical and biological activities that nourish a plant are surface actions, *i.e.*, they occur at the surfaces where soil, air, water and root coincide. The rest of the soil is mere anchorage. Anything that increases these surface phenomena is therefore bound to have a marked effect on plant nutrition and growth. Crumb structure provides optimum conditions.

Experience and experiment have established two incontrovertible points, firstly that cultivation of various kinds can modify soil structure for better or for worse, though continued cultivation always tends to destroy that structure, and secondly, that organic matter is the most efficient structure builder. On diverse crops in very dissimilar climates and agricultural circumstances it has been convincingly shown that excessive cultivation decreases crop yield. Some of this effect must be attributed to root damage, but structure and tilth enter into the matter. The world-over attention is being directed to systems of building up organic residues and humus in soils, without which soils are infertile and a prey to the severest ravages of soil erosion.

The connection between soil cultivation and fertility has recently been spotlighted by the publication of a book by Edward Faulkner, entitled *Ploughman's Folly* that has been a best-seller in America and England. In fourteen vigorous chapters the author maintains that the plough is the 'villain of world agriculture.' He holds that though in more primitive agricultural times the plough was a great boon in tackling the everlasting weed problem, it has outlived its usefulness. By continually reversing the clod it packs organic matter at the plough-sole thereby minimising its usefulness and establishing a pan which interferes with the plant roots and with the distribution of water and nutrients to them. In place of the plough Faulkner proposes the use of the disc-harrow and other implements of novel design that will incorporate organic matter more uniformly with the surface soil without turning the soil over, and without the formation of a plough-sole. He recounts his experiences, starting on the vegetable garden and extending to a field and farm scale, whereby he produced bumper crops on previously infertile land. In passing it should be mentioned that in

America where this experiment was carried out it is usual to reap only the ears of corn and leave the straw standing. The author explains how this standing straw is incorporated into the soil. He is no advocate of a fine clean tilth. A mulch of debris on the surface or the projection of butt ends of straw he regards with favour as a protection against soil erosion and moisture loss. There is a useful point here. The present writer was in Australia during the worst drought on record, and experienced, fortunately at a respectable distance, the intensity of dust storms caused by wind erosion. Untold thousands of acres of arable land have been devastated by deposited sand. The wheat lands of Australia are predominantly farmed on a system (it would be an exaggeration to dignify it by the name of rotation) of alternate wheat and fallow. The crop is on the land for approximately six or seven months. It is then allowed to remain vacant of any crop but weeds through the dry season, and the straw and weeds provide feed for sheep. With the onset of the rains, ploughing for a bare fallow starts with the dual object of keeping down weeds and preparing the surface for the penetration of rainfall which in areas of 10 to 20 inches per annum must be carefully conserved in the soil. This involves regular ploughing and cultivation during which time, amounting to about a year, there is no protective cover. In the past season it has been the general experience that on fields that for various reasons still retained a stubble, soil erosion was reasonably controlled. This is confirmed by experimental work in Saskatchewan.

*Ploughman's Folly* is full of speculation accompanied by a good deal of exaggeration and in some instances positive error. The would-be scientific explanations of the undoubted facts of experience are in many cases fantastic. Capillary water plays a prominent part in the argument but is consistently confused with the moisture present in channels that are not capillaries. In fact the author's procedure is rather reminiscent of the cynic's definition of philosophy. He finds bad reasons for supporting views which he believes on quite other grounds. As examples of exaggeration are his *obiter dicta* on soil nitrogen and weeds. He is satisfied that under his system the free-living (not leguminous) nitrogen-fixing bacteria in the soil can support maximum crops without fertilizers, and he says that the weed problem can be solved in two to five years. As an antidote to this optimism we may quote the results of two weed surveys. On the continuous wheat plots at the Rothamsted Experimental Station, Drs. Brencley and Warrington discovered no less than 230 million germinable weed seeds per acre within the ploughing depth. On one of the Tea Research Institute experiments, which has been subject to the usual monthly weeding rounds, the corresponding number to a depth of six inches varied between 60 and 100 million. The Rothamsted work shows that weed seeds have a peculiar periodicity in germination. Despite apparently ideal conditions and every aid to germination, some seeds will only germinate at specific times of the year. It seems improbable, to say the least, that a weed seed population of these dimensions can be entirely brought into favourable conditions in so short a time as that stated. Some seeds have a natural dormancy of many years' duration. In the Rothamsted work two years following operations reduced the weed population by only twenty per cent. Faulkner implies that the experiment stations have 'missed the bus,' to put it colloquially, in this matter of disc-harrowing and standing mulch. Here he himself is behind the times. H. H. Bennett, the Chief of the U.S.A. Soil Conservation Service, was summarising experiments on the subject a year or more before Faulkner's book was written and was describing the system as 'the most promising

conservation development of recent years.' Nevertheless when due allowances are made for the purple patches that seem bound to arise in popular descriptions of scientific subjects, this book is well worth reading as a reminder that the orthodox tradition is not sacrosanct.

From Russia and England come evidences of new and in some respects challenging views on the part played by organic matter in producing good soil structure. The old answer that humus is the chief factor does not seem to fit all the facts. For some time Russian workers noticeably Geltzer have been stressing the view that the part played by organic matter is more active when it is in process of decomposition than when it has disintegrated to humus proper. We know that vegetable remains break down under a process of microbiological fermentation when they are turned into the ground, and that this is accompanied by the formation of a sticky mucus. It is interesting to speculate on what part this mucus plays in the formation of soil crumbs. So far there has been no direct experimental determination of the process. Attempts in these laboratories to follow crumb formation when green manures were incorporated in soil failed to show any measurable effect during decomposition, but it is likely that in this instance the absence of effect was due to over-riding soil peculiarities. In Uganda, rapidly decomposing green manures, and composts past the fermentable stage have both failed to improve soil structure. It is not suggested that green manures are therefore without value in a soil, but that their beneficial effect is not one of structure-building.

The most recent Russian and English work, supplemented in Uganda, shows that the growing of crops improves structure and that their root action is the feature of prime importance. No organic matter can become more intimately mixed with the

soil than that derived from roots. Moreover, it has been shown that in the immediate neighbourhood of roots bacterial action is more intense than elsewhere. All roots are not of equal power in encouraging good structure; for example, leguminous species are less good than grasses, though a mixture of both is better than either separately. In dry climates it takes about four years for a grass sward to give the soil beneath it a good structure, and in humid temperate regions the process reaches its optimum in two years. When, by cultivation, the process is reversed, about the same length of time sees the complete loss of such improvement as has been achieved. On the basis of these investigations and much practical experience, particularly in war-time England, an extension of 'alternate-husbandry' is now being advocated. This consists of growing an arable grass crop for a period of years, and then turning the land to the production of other arable crops such as corn and roots before reverting once more to the arable grass or 'ley.' These leys produce better food for stock and greater quantities than run-out pasture, and their soil structure-building capacity is greater. It is point of special interest that the soil improvement is most marked if leys are ploughed before they begin to fall-off in production.

Here are two promising systems of cultivation which as yet do not dovetail into each other. Without using the 'villain of world agriculture' it does not appear that alternate-husbandry can make much progress, but it is possible to see prospects of using the plough on leys and withholding it on other crops.

What lessons are there to be learned from these experiences for those who are engaged in tropical agriculture, particularly when engaged in plantation agriculture with perennial crops? As far as general cropping with annual species is concerned

the Uganda work gives the plain lead for similar trials here, but our particular problem is different. We already have receded considerably from the position of intensive (and in the writer's opinion, unnecessary) cultivation. The combined agencies of tea, green manures and, be it admitted, weeds, keep our top soils very adequately filled with roots. We do not know how their efficiency compares with grass, or whether the tougher nature of tea roots is more beneficial for soil structure than the softer character of herbaceous species; but the fact that our soil volume is permanently occupied by roots in various stages of growth and decay may reasonably be put to the credit of our agricultural system. It may be that the most important part of our green manure crops is the root system and

that a mulch of loppings is, on the long view, as beneficial as forking-in, despite the fact that some nutrient loss is inevitable. In other words, that mulch *qua* mulch, if it is a *permanent* feature, may have a value as soil protection to compensate for the aforementioned nutrient loss. Our system of envelope forking if carried out on the contour is quite in accordance with the newer views about keeping a broken surface on land to restrain water and wind erosion. It seems unlikely that we can ever make use of a grass cover in conjunction with a crop like tea though such covers have been a standard practice in orchards. Be that as it may, the work described in this article gives an added stimulus to future research on cultivation, roots and green manures.