1. Introduction

In a study of the characteristics of a soil, its physical state manifests itself as being dynamic rather than static. This state, like other natural phenomena, is always changing, due to the multitude of external factors that exert their influence on it. The soil may be regarded as a three phase system in which the particles are the solid phase, the air the gaseous phase, and water the liquid phase. It is the balance that exists between these phases that is important to the plants growing in a soil and which makes the difference between fertile and infertile land.

Good soil agriculturally has a perfect balance between these phases. Where unbalance occurs, a deleterious effect on growth and development of plants ensues. When the system lacks water, plants die from drought. Lack of soil air exerts itself in stunted growth and may be caused by an over abundance of any of the other two phases in the soil system.

In this ever changing system, what are the factors that tend to cause an unbalance, and what are those that build up a good structure in the soil?

The solid particles in a soil vary from coarse sand to colloidal clay and it is the state in which they exist that plays an important role in the relationship between air and water in the soilsystem. If these particles are loose and present as a fine dust, neither water nor air can enter into the profile and, moreover, they are much more liable to be transported away by wind and water. A great deal of the fertility of the soil is thereby lost. On the other hand, if these particles are bound together in the form of aggregates, they will be much less liable to be eroded away and at the same time they will allow free access of water and air into the soil.

The genesis of soil structure refers to the causes and methods by which these loose particles are intimately grouped into aggregates. Its study forms a branch of soil physics which has been well investigated. The one important aspect that may be stressed in this investigation is that the formation of stable aggregates cannot take place in sands and silts where there is no colloidal material. This colloidal material may be present in the form of at least three distinct groups. They are, (1) clay particles

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themselves, (2) irreversible and slowly reversible inorganic colloids (such as the oxides of iron and alumina), (3) organic colloids. Without the material to work with, the process of aggregate formation cannot occur.

All available evidence seems to point to the fact that the amount of clay present is a salient feature in the ability of a soil to form aggregated stable particles. Not only is the total amount of aggregates in a soil dependent on the amount of clay, but also the extent to which the finer soil particles are aggregated together into larger secondary units. Thus the percentage of clay present in the form of aggregates, varies with the total amount of clay present in the soil. Apparently, clay particles function as binding agents.

Where there is an abundance of clay particles, it would seem that the effects of the other colloidal materials in the soil become secondary and, although they may help to increase the stability of aggregates, their importance is not as great as in soils containing small amounts of clay.

Baver and other authorities have put the amount of clay necessary for the bringing into significant effect of added organic colloids as less than 25 per cent. The addition of organic residues to soils in the form of well rotted Pen Manure or compost serves both as a medium by which nutrients are added and also creates suitable conditions for an increase in the biological activity of a soil. Micro and macro organisms flourish and from the point of view of the structural characteristics of the soil there is no doubt that the formation of stable aggregates is greatly enhanced. No final explanation of the mechanism of the cementation effects has yet been given. The mineral grains are thought to be surrounded by humus like substances that with the aid of the sticky action of the mucus of bacteria and fungal mycelium increase the resistance of soil structure. Geltser(24) advanced the hypothesis that the structure forming fraction of humus was composed of the autolytic products of bacteria. No other worker has substantiated this hypothesis though many have attempted to elucidate the biological factor in structure formation.

Martin and Waksman(25) found that the binding effect on soil particles produced by pure and mixed cultures of organisms was caused partly by the mechanical binding of fungal mycelia and partly by synthesized organic compounds. In sandy soils this effect of adding colloidal material such as humus seems to be of major importance to soil fertility. Demolon

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and Henin[26] have found that colloidal organic matter is more effective than clay in causing the formation of stable aggregates with sand. Myers[27] confirmed these findings using fine quartz sand and orthoclase particles as material to be aggregated.

The importance of the sesquioxidic materials in aggregate formation is difficult to assess, since the binding power of oxides of iron varies to a great extent on the external climate influences and internal moisture relations of the soil profile. In areas where for part of the year dehydration of the colloidal material will occur, stable aggregates may be formed. At the same time, a great deal of leaching of soil parent material must take place so that removal of colloidal silica may take place, and sesquioxidic material may accumulate. This cementing effect of sesquioxidic colloidal matter may therefore only be found in regions of high temperature and humidity where free drainage occurs and alternate drying out and wetting of the soil take place.

How may the physical properties of the soil be controlled so that a perfect balance between the phases of the system may be obtained and consequently the fertility of the soil be kept or improved? This is a question which is fundamental to all agricultural systems, whether looked into from the viewpoint of the individual farmer who wishes to increase his profits, or on the basis of increasing the stability of any national economy. It can be safely predicted that any system which does not take these points into consideration is doomed to failure from the start. The dust bowl of the United States is one of the vivid examples of such failure in modern times. It may be no exaggeration to believe that some of the greatest Empires of the Old World saw ruin and destruction because of their ignorance of the facts.

The methods available for the control of structure may be divided into three classes, namely (1) the proper use of cultivation implements, (2) the addition of manures, and (3) the choice of suitable crops.

The proper use of cultivation implements leads us to a consideration of tillage and soil tilth. Tilth has been defined as the physical structure of the soil in relation to plant growth and the art of tillage refers to the different mechanical manipulations that are necessary to provide suitable structures.

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It is obvious that the structural condition of a soil constitutes a major factor in tillage relationships. Since the object of soil preparation is to provide free entry of water and air into the soil mass for the use of the roots of the growing plant, it would seem that a study of the structural characteristics of the profile is necessary before the proper choice of implements may be made. For example, in soils with a loose structure in both surface and subsurface layers, the depth of ploughing need not be deep, whereas in the presence of subsurface pans it would be necessary for more intensive and deeper tillage to be adopted. The importance of the moisture content of the soil at the time of ploughing is admittedly great. This is a practical feature which can play an important part in the making or marring of the structure of a soil.

The effects of manuring with artificial fertilisers has often been considered to be harmful to the soil, but no conclusive evidence of this can be found in the literature except cases where large amounts of alkali salts have been applied to the soil. Lime and pen manure have been commonly considered the two fertilizers necessary for improving soil structure and the latter in particular has been found to be extremely effective on sandy soils. These facts will be discussed further in another part of this dissertation when the results of the manurial experiment are reported.

The growing crop can greatly alter the amount of stable secondary particles in the soil. Soils under permanent grass in particular show a more stable structure than soils which have had a succession of arable crops grown on them. These concepts will also be discussed further at a later stage.

With the three methods for control of the structural state of the soil given above, there seems a good chance that the practical agriculturist may gain an upper hand in the fight against the destructive forces of nature which, if allowed to go loose through mismanagement, will lead to ruined farms and devastated land. In the tropics where high temperature and rainfall accelerate leaching and erosion and other powerful agents of destruction, it is more important still to crop the land in such a way that its fertility is maintained or better still so that its level of fertility is improved. The supply of nutrients to the plant is important, but more important still is the need for keeping open the channels whereby these nutrients are taken into plants via the soil. The chemical aspects have been much discussed by agriculturists and scientists and have been

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offered as the solution to the problem of soil fertility. Nevertheless, it has been shown that fertilizer experiments do not give any responses on certain soil types or that the expected return has not been what was expected even where deficiencies of the essential elements occurred. "Look after the physical state of the soil profile and then use fertilizers", may well be the answer to the problem of getting higher yields from the land on both an individual and a national scale.