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Farming practices and soil structure

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Many of Western Australia's heavier textured wheatbelt soils have been farmed for 50 to 70 years. To the pioneers, they were the soils best suited to cropping. But today's farmers frequently complain that these soils are becoming more difficult to handle, that greater tractor power is needed to break them up, and that the length of time they remain in a workable condition after rains is becoming shorter.

These are indications that the structure of the soil has suffered as a result of years of cultivation. Research conducted by Department of Agriculture officers some years ago, indicated that these soils had suffered considerably in physical condition since clearing. In nearly every case the organic carbon content had dropped significantly, the soil density had increased and the pore space within the soil 'crumbs' had been reduced. Water was slower to penetrate, and the stability of the 'crumbs', or aggregates, had deteriorated.

This is not a sudden or obvious form of soil degradation. But because it has occurred, these wheatbelt soils now impose limits on plant growth...and hence crop yield and profit...which did not exist when these same soils were in a relatively good physical condition.

**What is soil structure?**

'Structure' describes the arrangement of the major soil constituents, that is sand, silt and clay, which are bound together by cementing agents, for example clay, organic matter, and certain iron and aluminium minerals, to produce soil aggregates. These aggregates are formed by many processes, which include the action of soil flora and fauna such as plant roots and earthworms, and drying and wetting.

The size, shape and distribution of these aggregates has a big influence on the nature of the air spaces, or pores, within the soil. These pores can be divided into three types:

- **Transmission pores.** These are larger than other pores. They occur usually between aggregates, and allow rapid movement of air and water through the soil. They are more vulnerable to degradation than smaller pores.

- **Storage pores** are smaller pores, mostly within aggregates, that hold water against gravity, but also allow this water to be extracted by plant roots.

- **Residual pores** are very small pores which contain water generally not available to the plant.

Man can modify an unsuitable soil structure. For example, by cultivation, he can produce a 'tilth' of the fine aggregates, which provides the seeds he sows with ideal seedbed conditions. Such an arrangement of soil aggregates means the soil contains enough transmission pores to allow easy root growth, seedling emergence, gaseous exchange and adequate drainage. It also contains enough storage pores to retain water for plants.

However, it is vitally important that an 'ideal' soil structure be stable, that is, able to withstand the
destructive effects of rainfall and mechanical manipulation. Any breakdown from the original ‘ideal’ soil structure may progressively limit plant growth. A common example of such a breakdown occurs when a surface ‘seal’ forms after heavy rain, and retards crop emergence when the crust dries out.

**Benefits of good structure**

Soil structure influences plant growth in many ways, both directly and indirectly. For example the structure of a soil determines the way heat and water will be held in that soil. Soil structure, in conjunction with the moisture content, also determines the mechanical strength and aeration of the soil.

In a situation where any of these factors are likely to limit production, the amount of structure in a soil, and the ability of the soil to maintain that structure, will be critical to the success of a crop or pasture.

Some of the benefits of improving soil structure are:

- Better rain infiltration. More water enters the soil, hence less runs off or evaporates from the surface of such soil. In regions where water is limited, this factor becomes even more important. Also, because of the quicker movement of water into and through the soil the land can be worked sooner after the season’s opening rains fall. This is particularly important on the heavier textured soils.
- Because improved soil structure reduces surface runoff, and presents more obstruction to the water that does flow, less water erosion and down-slope flooding occur.
- Improved aeration. This allows gases to be exchanged between the soil and the atmosphere, such that plant growth is not limited by either too much of a gas, for example, carbon dioxide, or too little of a gas, for example, oxygen, in the soil air spaces.
- Adequate soil strength. The best soil structure is one which maintains soil strength at a low enough level to allow seedlings to emerge easily and roots to grow uninhibited. It also should maintain enough soil strength to keep plant roots firmly anchored, and strongly resist surface damage from wind erosion and raindrop impact.

Also, the soil strength should be such that the surface remains in a rough, but not cloddy, condition after working as a further barrier to wind erosion.

The high soil strength in hardpans formed by the compactive forces exerted by tractor tyres and cultivation implements limits root growth, and therefore also limits a plant’s access to water and nutrient reserves. A better soil structure in a plant’s root zone will increase crop and pasture production, even on soils with a hardpan.

Furthermore, soils with good structure and hence moderate strength are easier to cultivate. This means better fuel economy, less wear on cultivator points, less stress on equipment and generally better seedbed conditions.

**Improving soil structure**

Farmers can gain real benefits from improving soil structure. The challenge is to devise
practical and profitable systems of agriculture which will improve the soil structure and the stability of that structure, and thus ensure the long term stability of agriculture.

Many aspects of farming can influence soil structure—rotations, stocking rates, tillage and soil amendments such as gypsum, all can influence soil structure for better or worse.

Here are some results of Western Australian research:

- **Effects of rotations and stock.** In 1961 soil researchers started an experiment at Merredin Research Station to follow changes in the structure of a Merredin loam soil under continuous pastures for varying numbers of years. Parts of the barrel medic—annual ryegrass pasture were cropped to wheat after five, six and seven years pasture.

  Soil structure tests indicated that the water stable aggregation—a measure of soil structural stability—continued to improve throughout seven years of undisturbed pasture, but was rapidly reduced to a low level by even one year of cultivation and cropping (Figure 1).

  As part of the same trial at Merredin Research Station they devised an experiment to test the effects of grazing sheep in winter, when the soil is wet. From Figure 2 we can see that the soil structural stability has suffered as a result of winter-grazing. Other trial results show that high stocking rates cause more harm to the soil structure than do low stocking rates.

- **Effects of gypsum.** Gypsum has been used for many years to improve soil structure in other parts of the world as well as in Australia.

  Gypsum has a two-fold beneficial effect on soil structure. First the calcium in the gypsum replaces sodium on the surface of the clay particles in the soil. Secondly it increases the electrolyte concentration in the soil water. Both of these factors create conditions which favour both aggregation and stability of existing soil aggregates.

  Gypsum can improve some soils which surface-seal or crust, so that:
  - rain infiltrates better,
  - the land can be worked sooner after the season’s opening rain, and for a longer period of time,
  - more seedlings emerge, and
  - the soil remains in a relatively friable state.

  Departmental trials in the 1960s assessed whether gypsum use would be economic on some soil types. Yield increases were recorded on only a low portion of sites, but researchers conclude that some troublesome soils could be treated economically if cheap local deposits were available.

  However the risk of soil structure deterioration has increased further with the trend towards more frequent cropping and continuous cropping. Thus the role of gypsum in improving soil structure and plant production needs further study. In the Department’s two gypsum trials conducted in 1982 at Merredin, gypsum gave a 27 per cent increase in wheat yield on a crusty grey clay soil and a 17 per cent increase in wheat yield on a non-crusting red salmon gum-gumlet soil.

  Observations also support the view that gypsum may make seeding possible on some sites which would otherwise be too soggy to crop. Further work is needed on predicting which soils will respond to gypsum and whether the responses will be economically justifiable.

  - **Effects of various tillage systems and deep ripping.** Generally we can say that when cultivating a soil, the more work a tillage implement has to do, the more damage it does to the soil structure. Thus, implements which “smash” the soil will disintegrate the existing soil structure much more than implements which use existing planes of weakness in the soil to form the seed bed. For example in a trial at Wongan Hills a disc plough did more harm to soil structure than did a scarifier.

  Furthermore, increasing the number of “runs” a particular cultivation implement does, and to a lesser extent the speed of cultivation, we do more work on the soil and get more break-down in soil structure.

  For example, in a continuous cultivation trial on a red sandy clay loam at the Merredin Research Station, the soil structure has been much more severely degraded after six years by an extra two cultivations each year, than by direct drilling. In the past two years this soil structure deterioration resulted in much poorer seedling emergence, wheat growth and yields on these conventional cultivation plots.

  **Table 1.** Continuous cropping tillage trial on heavy-textured soil at Merredin. (In sixth year of crop)

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<td>Direct drilling (combine)</td>
<td>1190</td>
<td>1002</td>
<td>994</td>
</tr>
<tr>
<td>District practice (two extra cultivations)</td>
<td>568</td>
<td>582</td>
<td>580</td>
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  Deep ripping can be used to alleviate poor structural conditions, such as compaction, at depth in a soil. It does this by loosening the subsoil, making it less dense overall, and giving plant roots access to water and nutrients they would not have gained otherwise.

  Deep ripping results in the past few years were very encouraging on light soils with a compacted layer at about 20 cm depth, but variable on heavy and medium texture soils. There are possible disadvantages from deep ripping soils with very acid subsoils, for example Wodgii soils, as bringing these subsoils to the surface may affect seedlings adversely.

- The effects of continuous cropping, using direct drilling (top) and conventional cultivation practices.