Hardpans – a focus upon those created by human activity

1.0 Introduction

1.1 There is a lot of confusion about what Hardpan is, not surprisingly because there are so many types of Hardpan. Although they can be covered by the word compaction, this is not always accurate.

1.2 What is well documented now is that, although the soil is made up of mineral "aggregates" ranging from coarse sand through silts and loams to fine particled heavy clay, it is the many multifarious living organisms that make the soil from inert "dirt" into the healthy and fertile medium needed to grow crops.

1.3 It is this fertility created by the web of life existing within the mineral components of the soil which can be so badly affected by Hardpan.

2.0 Soil Compaction

2.1 Compaction takes place when the soil structure created by the living organisms is collapsed.

2.2 This can be caused commonly by heavy loading (a vehicle or constant foot traffic for example) or extreme events such as a landslide or an intense fire.

2.3 Soil compaction results in the area of compaction being unable to support the rich range of life forms so necessary to a productive soil, due to the collapsing of the structure of that soil. (picture)

3.0 Hardpans – natural and induced.

3.1 Naturals - Hardpan can be an extreme form of compaction. It is extreme because it takes place over a wide area. Hardpan can exist naturally without compaction - there are examples of naturally occurring hardpans in laterite soils caused chemically – and shallow bedrock hardpans which are often impervious. These are not the subject of this paper.

3.2 human induced.

3.2.1 Plough pan –

3.2.2 In the 1930s in mid America there was a well-documented agricultural disaster known as "the dust bowl". The result was a catastrophic loss of topsoil through (mainly) wind erosion resulting in prolonged and severe dust storms.

3.2.3 A key cause of these dust storms was the loss of soil structure in the topsoil by excessive tillage. But there was an underlying (literally) cause of loss of fertility as well.

3.2.4 At the depth of the "shoe" of a plough or the bottom section of a disc plough, something insidious had been happening. Soil above the plough was being loosened and turned over, but below that plough an equal and opposite reaction resulted in compression of that lower soil to create a compacted layer.

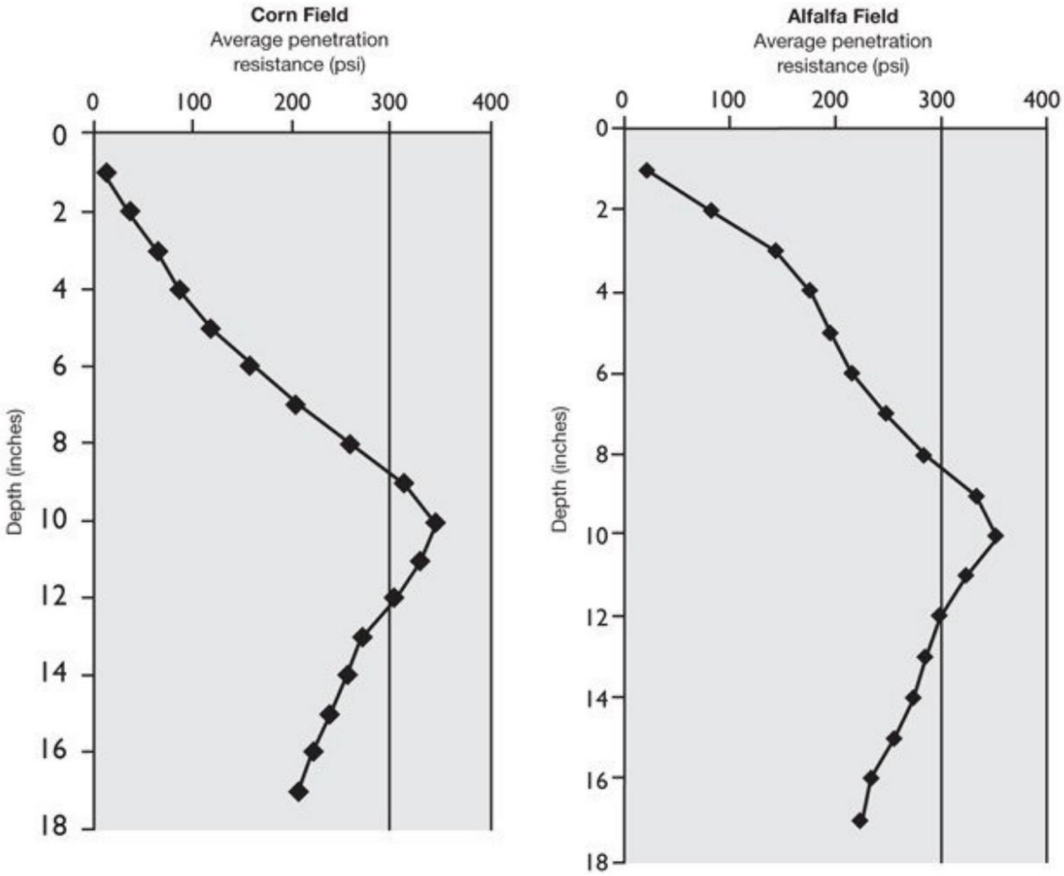
3.2.5 The plough pan caused became very obvious after the wind had removed all the loose topsoil, leaving a hard ground with the marks of the plough embedded there. It was the continual tilling of the land year after year which resulted in an ever-increasing hardpan also increasing in depth over the years.

3.2.6 Similar problems were being encountered in Brazil. A report on soil conditions (Shaxson, Williams, Kassam identified widespread problems of hardpans caused by disc ploughs (see picture 1 below with quote from the report) *"Subsurface compaction ('panning') due to repeated annual disc--tillage on a (pedologically 'deep') soil in the Brazilian cerrado region. (Soil auger for scale). (Photo: T.F.Shaxson)"*

Picture 1. Disc plough marks in underlying hardpan

3.2.7 Roll forward to 2014 and the State of Pennsylvania published a report looking at the then current plough pan in its soils. https://extension.psu.edu/effects-of-soil-compaction The dust bowl mistakes had been corrected - or so it appeared, because the soil is not been blown away. So! what is this State report about?

3.2.8 **Compaction!** Using a penetrometer, it was found that the deeper into the soil, the greater the compaction until around 250mm and below that compaction started to reduce. This is where the "knee diagram" first appeared, showing maximum compaction at around 250 mm below the surface – about the same depth as a disc plough.



The soil in this study was most densely compacted around 10 inches or some 25cm below the surface. If topsoils are tilled, but to insufficient depth, (that is, still above the "knee" in these diagrams, which is the point of highest soil density) the hardest layer is left intact-the Hardpan remains!

3.3.1 Surface Pan –

3.3.2 If bare soil is exposed to the elements, it will nearly always be in danger of deterioration. In nature, bare soils are uncommon and for it to be bare, some specific event will have occurred to make it so – be it a fire, a landslide, a flood or a severe drought.

3.3.3 A raindrop falling at its terminal velocity will hit any bare soil with great force. And after many drops, the top few millimetres of soil will compact. Follow that rain with sun or wind and the bare wet soil will dry out on the surface and become a hard surface layer – Surface Pan.

3.3.4 This can be broken up manually very simply, but if it is not, then the next rain that falls will hit that surface hardpan and tend to runoff. It will not percolate easily.

3.4 Foot traffic pan –

3.4.1 Look at any well-used footpath across land and you will see bare earth exposed where nothing is growing. The reason nothing is growing is <u>not</u> because feet have crushed the plants but that compaction has taken place, collapsing the soil in to a solid mass that cannot support life. In the case of a footpath there is a linear compaction. So how does Foot Traffic **<u>Pan</u>** get made? "Pan", meaning over a large area rather than in a linear path.

3.4.2 In Malawi, until the 1920s, most farming was based on "shifting cultivation", a method then widely used in S E Africa. It involved scattering seed and seedlings over an area of land having burned the foliage off it first, and farming the land for 2 or 3 years before it lost its fertility, when the farmer would move on to another piece of land. The soil would recover and after a few years the farmer might return to that land to farm it again. (See The Nyasaland Survey Papers 1938-1943 Berry and Petty ISBN 0-9509470-2-4)

3.4.3 This worked with a population in Malawi of about 1 million but as the population started to grow, farmers started to remain on the same land permanently and in order to keep fertility, they started to use hoes to form ridges to grow the crops. (Population in 2023 estimated at 20 million).

3.4.4 Every year they would take the ridges used to grow the previous year's crop and split them in half, pushing half the ridge one way and half the other way into the adjacent ridges. In other words, the new cropping ridges would be positioned directly over the previous year's furrows.

3.4.5 These furrows had collected water and also been used by the farmers to walk in while they tended or harvested the crops. So, the furrows acted as informal footpaths. The following year they would do the same ridge splitting, bringing the new ridges over the previous year's "footpaths", and so on.

Picture 2. Foot Traffic Pan

3.4.6 This was a very effective (and ultimately, disastrous) way of ensuring that the whole fields would become compacted, increasing each time the new ridges were formed on top of the compacted furrows.

3.4.7. Over the years, this foot traffic covered the whole areas of the fields several times and often doing so in wet weather. This resulted in the formation of **foot traffic Pan.**

Picture 3 – Only a thin layer of soil above the hardpan

3.5 Hoe Pan –

3.5.1. Hoe pan is caused by long term use of the hand hoe. By the late 1930s, most farming in Malawi was "static" meaning that cultivation bad pretty much phased out.

3.5.2 Growing population pressures and the limited farmable land available meant that agriculture was becoming more intense. The ridge and furrow method was widely used, and effective crops were grown for many years.

3.5.3 But there was an insidious problem being created and over the next 70 years, culminating in the FAO report in 1999, soil was losing its fertility. Increasing amounts of fertiliser were needed to maintain food crops.

The FAO report TCI Paper Series No 10 in November 1999 by Shaxson and others was titled:- "An Investigation into the Presence of Cultivation Hoe Pan under Smallholder Farming Conditions". Paragraph 28 on page 7 makes it very clear that rootzone improvement and water percolation as a result of *breaking the hoe pan* is recommended.

3.5.4 FAO reports in 1997 and 2016 (ISBN 978-92-5-109516-4 (FAO) identified that 29 tonnes of topsoil were being lost from every hectare of farmed land in Malawi – every year. Severe periods of hunger were being experienced. Flooding and siltation were become more common.

3.5.5 At one hoe depth down into the soil a hard layer of compaction had been forming since hoes had started to be used extensively in the 1930s. So, added to 70 years of foot traffic pan, was also 70 years of hand hoe use – and the resultant **Hoe Pan**

3.5.6 The constant use of hoes to till the soils added to the density of the hardpan – those hoes carrying out a similar damaging process that took place back in the dust bowl in the mid-west of America in the 1930s.

3.5.7 When a hoe, with its blunt leading edge, is wielded by a farmer, it penetrates the soil at an angle (typically at about 45 degrees) and all the materials above the hoe blade are loosened and aerated. BUT! For each action there is an equal and opposite reaction and here there is no exception. The soil beneath the hoe blade is compacted. The farmer does this year after year. The compaction becomes increasingly dense.

3.5.7 This widespread development of hardpans in nearly all areas of Malawi has resulted in a degradation which is continuing year on year.

3.5.8 The joint effect of foot traffic pan and hoe pan means that neither water not roots can penetrate the hard layer, so the rootzone is less than it should be and the crops are extremely vulnerable to a dry period during the growing season (which is becoming increasingly common due to climate change). Rain does not percolate into the topsoil and top aquifer but mainly runs downhill over the surface. (see picture 4 below)

Picture 4. Surface runoff

3.5.9 Bad crops are bad enough, but then because the water runs off so quickly (because it cannot percolate the subsoil because of the hardpan), the land suffers from catastrophic erosion, flooding, siltation and water loss. These are some of the effects of **hoe pan**. (see picture 5 below)

Picture 5 – catastrophic erosion down to the Hoe Pan.

4.0 Summary –

4.1. Hardpan is a potential problem wherever humans interact with soils. Good Land Husbandry will ensure that these hardpans are removed, reduced or never formed in the first place.

4.2 The role of "No Till" is important in achieving this. However, no till on land with severe hardpans will not be effective until that hardpan is broken.

4.3 It can be broken biologically with sufficient time, however the quickest and most effective way of dealing with it is to break that hardpan physically. Clearly this is a very heavy task and many farmers might be daunted by this.

4.4 Small areas of land can be broken by pickaxe and there are a range of other more mechanical ways of breaking larger areas – and considerable research on this is in progress. Great care must be taken when using nachinery, not to create an even worse hardpan at a greater depth.

4.5 Once the harpan is broken, it is best to apply "no till" principles for good soil health and water conservation.

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