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Soil drying requirement for mobility of heavy combine harvesters in rice fields

(Keperluan pengeringan tanah untuk pergerakan jentuai berat di tanah sawah)

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Key words: cone index, soil water content, groundwater, drying duration, mobility, heavy combine harvester

Abstrak

Nilai indeks kon 3.0 dan 5.0 kg/cm^2 masing-masing merupakan daya kekuatan tanah yang minimum dan paling sesuai untuk pergerakan jentuai berat di tanah sawah. Dengan berpandukan nilai-nilai tersebut sebagai sasaran, satu kajian dibuat untuk memahami proses pembentukan kekuatan tanah setelah mengalami pengeringan semulajadi tanah dan susutan aras air tanah.

Pengaruh kandungan air tanah terhadap indeks kon menjadi lemah dengan meningkatnya ketumpatan pukal. Sehubungan dengan ini struktur tanah, terutamanya di lapisan kematu, harus dikekalkan agar nilai ketumpatan pukal tidak menurun. Sekiranya gagal berbuat demikian, pengeringan yang intensif adalah perlu untuk membentuk semula daya kekuatan tanah.

Indeks kon 3.0 kg/cm^2 boleh diperoleh setelah 9 hari kering berterusan, kandungan air tanah menurun ke tahap 0.58 kg/kg dan aras air tanah susut lebih dari 40 cm. Apabila keadaan kering berlanjutan sehingga sekurang-kurangnya 17 hari, indeks kon meningkat kepada 5.0 kg/cm^2 di bawah tahap 0.45 kg/kg bagi kandungan air tanah serta 65 cm bagi aras air. Kadar pengeringan yang sedemikian sangat sukar dicapai. Oleh itu strategi-strategi tertentu untuk pengeringan mestilah dipraktikkan.

Abstract

Cone index values of 3.0 and 5.0 kg/cm^2 represent the minimum and ideal soil strength respectively for mobility of heavy combine harvesters in rice fields. Using these values as targets, a study was done to understand the process of soil strength development as induced by natural soil desiccation and lowering of groundwater level.

The influence of soil water content on the cone index diminished as the bulk density increased. It is important that soil structure particularly at the hardpan, is preserved to ensure that the bulk density is not reduced. Unless so, intensive soil drying will become necessary for soil strength development.

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A cone index of 3.0 kg/cm^2 was obtained after 9 days of continuous drying when soil water content was at 0.58 kg/kg and the groundwater level decreased by more than 40 cm. Extended drying to a minimum of 17 days produced a cone index of 5.0 kg/cm^2 with soil water content at about 0.45 kg/kg and the groundwater level at 65 cm below the soil surface. It is difficult to achieve such rates of soil drying. Therefore, a practical drying strategy has to be adopted.

Introduction

The soil bearing capacity standards for mobility of heavy (6.0 t) Western combine harvesters in rice fields was established by Shigyo (1981) using the average cone index values for the first 30-cm layer. The values were given as 3.0 and 5.0 kg/cm^2 for the minimum and ideal level of mobility respectively. However, such standards are of little value unless accompanied by a precise definition of field condition under which the designated cone index values can be achieved.

A practical method towards achieving improved soil bearing capacity is through desiccation and drainage. Ezaki et al. (1976) reported that soil hardness is dependent upon the extent of soil drying. A marked increase in cone index within the first 20-cm layer can be achieved after the groundwater level exceeded 30 cm below the soil surface. Yamashita (1984) indicated that the soil bearing capacity increases up to 2.0 kg/cm^2 within the 0–25 cm layer when the soil water content falls below 0.60 kg/kg. This was obtained after 9–17 days of continuous drying. In a laboratory simulation, Anyoji (1986) discovered that the percolation of gravitational water had only a small effect on the rate of hardening of heavy clay soils. This was because the percentage of gravitational water over that of soil porosity was low (6.3%). Soil bearing improvement then will have to depend strongly on evaporation losses.

The purpose of this study was to further understand soil strength development as induced by the natural processes of desiccation and groundwater lowering. Using 3.0 and 5.0 kg/cm^2 as target cone index values, the study sought to quantify field drying requirement for mechanical harvesting. A simple but practical soil drying guidelines will be proposed for water managers, farmers and harvesting contractors.

Materials and methods

The study was conducted in the padi fields at Permatang Pauh, Seberang Perai. The soil is clay loam of the Kundor/Tualang association. Some characteristics of the soil are presented in *Table 1*. The particle-size analysis was done by using the hydrometer, bulk density by core method and organic matter content by Walkley-Black method. The study was carried out during the crop harvest period of February and March, 1987.

The three main parameters evaluated were soil bearing capacity, soil water content and groundwater level. Data were collected simultaneously for all the parameters at drying duration of 3, 7, 11, 14 and 17 days. Drying duration is defined as the number of days subsequent to complete surface water removal from the field.

Sampling points were arranged in a line perpendicular to an existing drain. A total of 10 points spaced at 10-m apart was established. Three replicates were made at each sampling point, giving a total of 30 sets of data for each parameter studied.

Soil bearing capacity in the form of cone index values were taken at every 5.0-cm depth using cone penetrometer of the proving-ring type with a cone base area of

Table 1. Particle size distribution, bulk density and organic matter content according to soil depth

Soil depth (cm)	Particle size distribution (%)			Bulk density	Organic matter content (%)
	Clay	Silt	Sand	Mg/m^3	
0–10	34	38	28	0.94	7.52
10–20	42	38	20	1.12	7.22
20–30	40	40	20	1.17	5.24
30–40	40	42	18	1.18	3.21

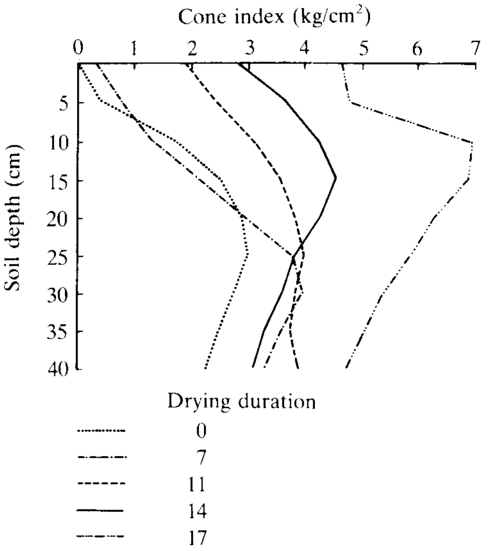

Figure 1. Changes in cone index with soil depth at various drying durations

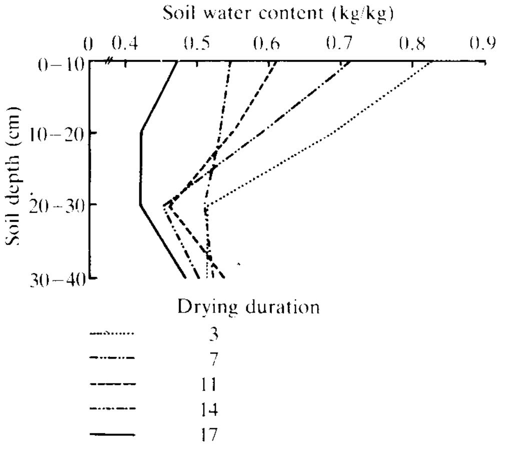

Figure 2. Changes in soil water content with soil depth at various drying durations

6.45 cm^2. Soil water content, sampled at every 10 cm, was obtained through gravimetric analysis. Groundwater level was observed from auger holes 10 cm in diameter with PVC casing to support the top 50-cm layer.

Results

Effective soil drying was obtained for 17 continuous days. Rainfall interruptions during the experimental period did occur on drying duration of 1, 4 and 8 days but with negligible amounts of 0.4, 0.2 and 0.4 mm respectively. Groundwater level lowering was unhindered as the surrounding drains functioned very well with free-flow maintained at a depth below that of groundwater. The average daily sunshine during the treatment period was recorded at 7.5 h.

The changes in cone index values across the soil profile during continuous drying are illustrated in *Figure 1*. Generally, cone index increased with soil depth. However, up to a certain depth, the trend was reversed depending upon the drying duration treatment. Up to drying duration of 11 days, cone index peaked at 25-cm depth. Further drying (14 & 17 days) caused cone index to peak at 15-cm depth. A relatively marked increase in cone index with drying occurred above the 25-cm layer as opposed to the layer below. This was most pronounced after drying for 7 days.

Changes in soil water content at various soil depths is shown in *Figure 2*. Irrespective of drying duration treatment, soil water content decreased with

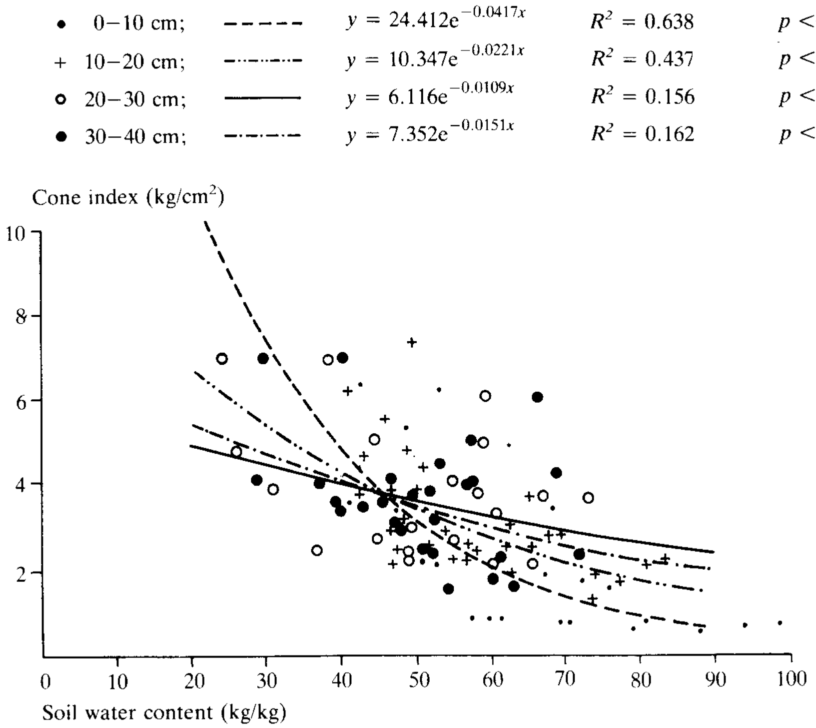

Figure 3. Relationship between cone index and soil water content of various soil depths

increasing soil depth up to the 20–30 cm profile below which it increased with depth except for that of 3-day duration. This trend corresponds to the increase in cone index described earlier, thus indicating an inverse relationship between cone index and soil water content.

Further analysis as shown in *Figure 3* revealed significant influence of soil water on cone index with the strongest response

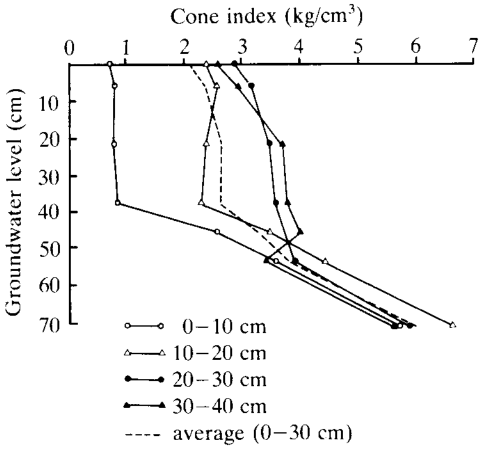

Figure 4. Relationship between cone index and groundwater level at various soil depths

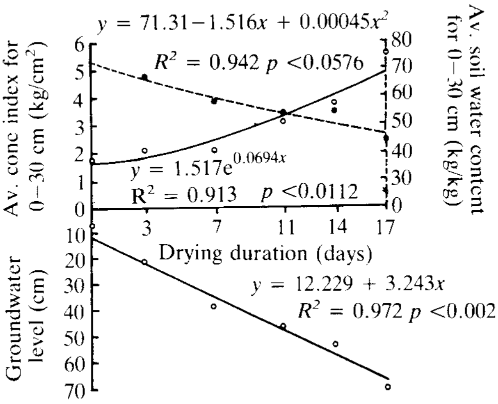

Figure 5. Development of cone index in relation to drying duration, moisture content and groundwater level

obtained at the topmost layer (0–10 cm and 10–20 cm). At deeper soil depths (20–30 cm and 30–40 cm) the cone index values were less responsive to soil water content.

It is postulated that the differential response of cone index to soil water could be related to the soil physical properties such as bulk density. The 10-cm layer that responded strongly to soil drying is actually the puddled layer where the bulk density was lowest at 0.94 Mg/m^3 *(Table 1)*. Below this layer the relationship between cone index and soil water weakened as bulk density increased.

A part of the soil drying process is lowering of groundwater level. *Figure 4* illustrates the influence of groundwater level on cone index values. There was a slight increase in cone index values with decreasing groundwater level up to 40 cm below soil surface. Further decreases in groundwater level then increased the cone index values drastically, particularly for the top 20-cm layer. Ezaki et al. (1976) reported similar trends but at a groundwater level of 30-cm below soil surface.

Based on all the information obtained, field drying requirement for mobility of heavy combine harvester is presented in *Figure 5*. The cone index and soil water content values were taken as the average values for 0–30 cm soil depth in conformance to the standards of Shigyo (1981). The minimum cone index requirement of 3.0 kg/cm^2 for mobility was achieved after 9 days of continuous drying with final soil water content of 0.58 kg/kg and groundwater level at more than 40 cm. For ideal mobility at cone index of 5.0 kg/cm^2, a minimum of 17 days of drying was necessary to reduce soil water content to about 0.45 kg/kg and lower groundwater level to 65 cm below soil surface.

Discussion

The hardpan formation, characterised by high cone index values including the peak, was located within the 15–25 cm layer. Above this, where the initial cone index values were low but subsequently increased significantly with drying, was the puddled layer. According to Sharma and De Datta (1985), the destruction of soil structure due to puddling caused significant reduction in bulk density and soil strength. Therefore, it is suggested that with the destruction of soil structure, soil water content becomes an important factor influencing soil bearing capacity.

The implication of this observation is that soil structure must be preserved or else extensive soil drying would be necessary for soil bearing development. Tillage and ruts caused by wheel sinkage should not exceed 10–15 cm to preserve the structure of the hardpan. Fukushi and Iwama (1982) observed that hardpans tend to occur deeper in soils subjected to heavy machines. In such cases intensive soil drying at deeper depths will be necessary to strengthen the soil for machine mobility.

The drying requirement of 9 and 17 continuous fine days to achieve minimum and ideal soil strength respectively for combine harvesting are reasons for worry. In an analysis of rainfall pattern in the Muda Irrigation Scheme, Anyoji (1986) reported that more than 9 continuous fine days is experienced once in two years in the months of December to April and June to July. January, February and March are also capable of achieving more than 17 continuous fine days. An annual occurrence of more than 9 continuous fine days can be expected from December to March only.

The rainfall pattern in the other granary areas is similar if not worse. Unlike Muda, Kemubu experiences only one distinct dry season annually. In

Seberang Perak, rainfall is quite evenly distributed throughout the year. With double cropping and crop staggering, mechanical harvesting will definitely encounter adverse soil and weather conditions.

To counter such unfavourable weather pattern, it is proposed that soil drying takes maximum advantage of available dry spells. It was observed that after 7 days of continuous drying, a dramatic increase in cone index can be expected although the targetted cone index values may not be met. Such a dry spell is available in Muda occurring annually in all months except May, September, October and November. Harvest periods in Muda for example, should therefore be scheduled to fall between December to March (main-season) and July to August (off-season). Earlier (3–4 weeks) surface water removal before harvest together with an efficient drainage system can enhance the probability of achieving adequate soil drying.

For long term measures, techniques for soil structure and hardpan preservation need to be considered. Prolonged dry fallow period, dry tillage and soil amelioration practices may be useful. Development of combine harvesters with low ground contact pressure should also be explored.

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