Identifying the interrelationships between soil properties affecting the surface structural stability of soil used for cotton production.

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Introduction

Previous studies of soil used for cotton production has highlighted that soil structural decline may be a potentially one of the limiting factor restricting cotton growth (CRDC report MCK 1C & MCK 2C). Surface soil aggregates of soil used for cotton production will slake and/or disperse in water. The implications vary according to the scale at which this phenomenon occurs. Generally slaking is a desirable process in terms of surface soil structural regeneration, a process termed self-mulching. If slaking is excessive, resulting in aggregates < 100 μm in diameter, there is a chance that a temporary surface crust may form (Loch, 1995). Further, if the slaked aggregates disintegrate to producing sand, silt and clay, an undesirable massive structure may result. Water and air movement, root penetration and function, and seedling establishment often are affected adversely (Field, 2001).

In order to identify the potential for surface soil structural decline two soil stability procedures have been identified by the industry. One of the procedures is termed the aggregate stability in water test (*ASWAT*), developed by Field *et al.* (1997), which is a diagnostic procedure used to assesses the degree of dispersion aggregates experience when immersed in water. The advantage of the test is it requires little specialised equipment, is relatively expedient making it satisfactory for routine use by land managers in the field or at home. Consequently the ASWAT procedure has been incorporated into SOILpak for cotton growers (3rd edition) making it accessible to workers in the cotton industry. The other procedure identified by industry is a modified end-over-end technique. This procedure is used to assess the rate at which surface soil slakes and/or disperses. By comparing these surface soil breakdown dynamics it is possible to assess the potential for a surface crust to form.

Understanding and managing the optimal function of soil for cotton production, in part, requires the assessment of soil properties that influence the surface soil structure, which include clay content, soil organic matter, exchangeable cations (sodicity), and soil inorganic carbon (lime). Routine analysis of soil supplies information that is useful in managing the basic soil properties that influence surface soil structure yet, the interrelationships of the basic soil properties needs consideration. Considering the interrelationships is necessary because no one property can account for changes in surface soil structure and, that the significance of each soil property will depend on its interrelationship with other soil properties affecting the surface structure.

Thus, the aim of this paper is to illustrate the importance of identifying the interrelationships between influential soil properties affecting cotton soil function using surface structural stability as an example.

Method overview

The two soil stability tests used in this paper are the aggregate stability in water test (*ASWAT*) and a modified end-over-end shaking procedure. For the *ASWAT* procedure some 80 soil samples were collected from a dry-land cotton site near Dalby and from 2 sites near Narrabri and Warren used for irrigated cotton production. For the *ASWAT* procedure the soil manipulations and subsequent scoring procedure are comprehensively described in Field *at al.* (1997) and the SOILpak 3rd. The scores from this diagnostic procedure enables the distinction between spontaneous dispersion (*ASWAT* > 6), dispersion after mechanical disruption of wetted soil (*ASWAT* 1-6) and resistance to spontaneous dispersion and dispersion of mechanically-disrupted aggregates (*ASWAT* = 0), to be made.

The more rigorous end-over-end procedure modified from Loch (1994) and So *et al.* (1997) can be used to assess surface soil slaking in addition to surface soil dispersion. Some 20 surface soil samples from cotton growing areas near Dalby, Narrabri and Warren were used in this procedure. The air-dry equivalent of 6 g of oven-dry soil is immersed into 100 ml of deionised water and end-over-end at 30 rpm for various time periods up to 6 hours. The degree of soil slaking is determined by measuring the oven-dry mass of the aggregates and sediment that remains on 100 μm sieve after gentle wet sieving. The amount of dispersed material (< 2 μm) is determined using the pipette method on the material that has passed through the 100 μm sieve. The rate at which each soil slakes and disperses is fitted with and exponential increasing. An approach described by described by Zanini *et al.* (1999) is adopted to simplify the resulting soil slaking and dispersion curves into a single scale factor. The procedure involves identifying a scale mean curve and, the multiplication of the individual slaking and dispersion curves by the corresponding scale factor will translate the curve to the scale mean curve. Thus, a scale factor with a value less than one indicates a soil that is prone to excessive slaking and/or dispersion, whereas a scale factor greater than one indicates a soil that is not prone to excessive slaking and/or dispersion.

Selected soil properties known to influence the potential slaking and dispersion of soil were carried out on the samples after air-drying and gentle grinding. Influential soil properties analysed for include; clay content (Gee and Bauder, 1986), exchangeable sodium percentage (*ESP*) and the *Ca/Mg ratio* (Tucker and Beatty, 1974), soil organic carbon (*SOC*) and particulate organic carbon (*POC*) (Merry & Spouncer, 1988; Cambardella & Elliot, 1992), and total inorganic carbon (*TIC*). Classification trees (Odeh *et al.*, 1994) are developed to illustrate the interrelationship between influential soil properties affecting the resulting surface soil stabilities classified by the *ASWAT* and modified end-over-end procedure.

Results and discussion

Conventionally the relationship between influential soil properties and surface soil stability are presented as critical values, linear and/or curve linear relationships. An alternative approach is the use of classification trees, which enables the interrelationships of several influential properties to be observed. The classification trees presented in Figures 1 and 2 are developed using the most influential soil properties affecting surface soil stability assessed using the *ASWAT* and modified end-over-end procedures, respectively.

The "dispersion classification tree" combining the interaction of physico-chemical properties affecting the diagnosis of dispersion using the ASWAT procedure is presented in Figure 1. The terminating nodes represent samples prone to spontaneous dispersion (node 1), dispersion after mechanical disruption of wetted soil (node 2) and samples resistant to dispersion (node 3). The initial criteria distinguishing most samples in Figure 1 comes from the observation that soil with clay contents of less than 50 % are not generally prone to dispersion. Although, a small number of samples within this group did disperse after mechanical disruption meaning working of the soil while wet should be avoided. This observation demonstrates the affect the interrelationship between clay content, Ca/Mg ratios < 2 and ESP > 2 has on dispersion after mechanical work allocating these soil samples to node 2. For samples with clay contents greater than 50 % it is found that the probability of dispersion is depends on the interactions

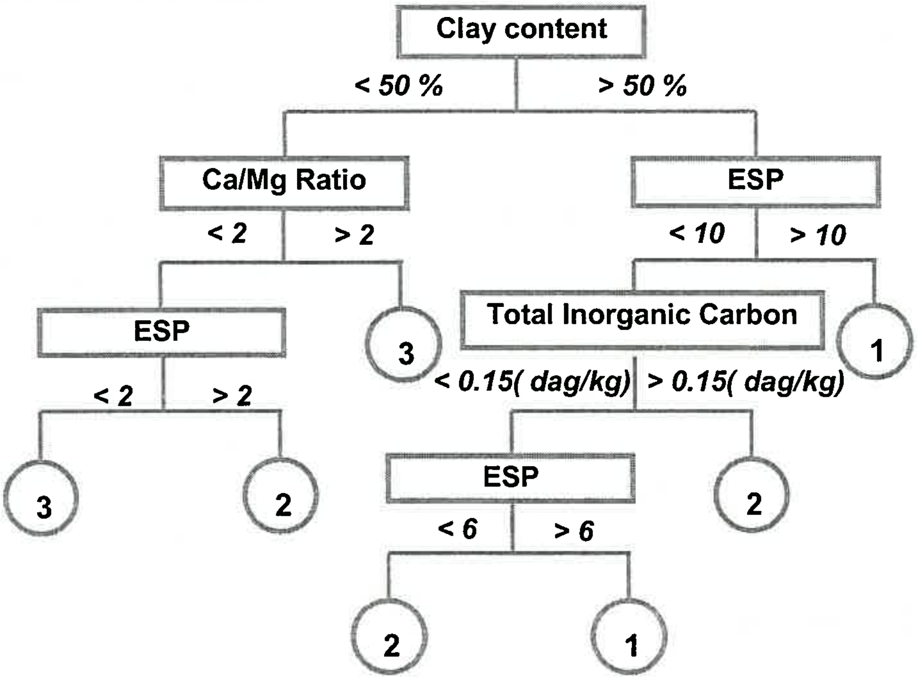

Figure 1. Hypothesized classification tree defining the critical limits and illustrating the interrelationships of influential soil properties terminating at nodes diagnosing the types of dispersion described by the *ASWAT* procedure.

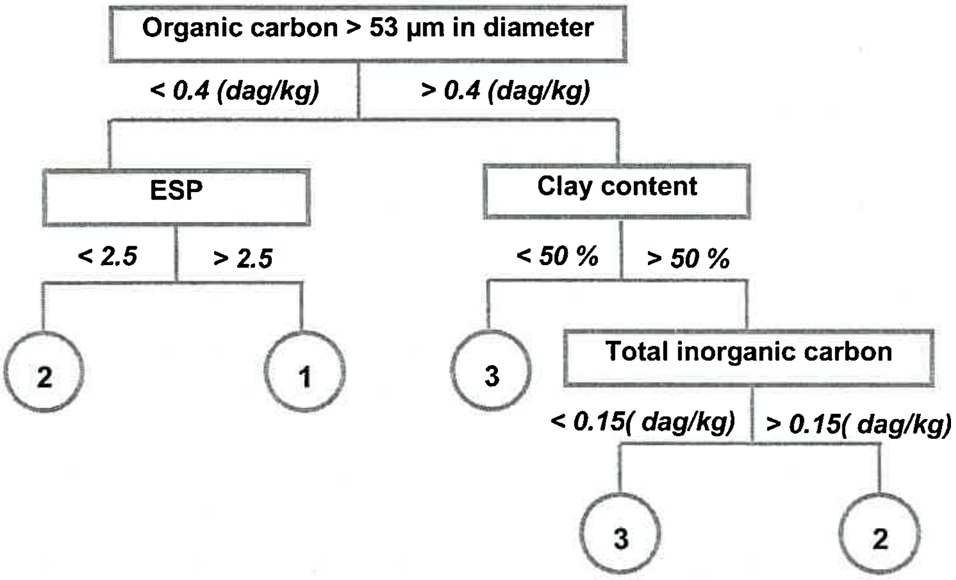

Figure 2. Hypothesized crusting classification tree defining the critical limits and illustrating the interrelationships of influential soil properties terminating at nodes categorsing the soil into dispersion prone (1), crusting prone (2), and unlikely to crust or disperse (3).

between clay content, *ESP*, and *TIC*. For soil with and *ESP* > 10 spontaneous dispersion will most certainly occur, irrespective of the interactions with other soil properties measured. The interaction between *ESP* and *TIC* suggests that soil with sufficient amounts of *TIC*, even if the *ESP* > 6, would not suffer spontaneous dispersion as expected. Soil with *ESP* < 6 usually does not result in spontaneous dispersion but, mechanical working of the soil may result in dispersion.

The "crusting classification tree" combined the interactions of the measured physico-chemical properties affecting the soil slaking and dispersion is presented in Figure 2. The terminating nodes categorise the soil matrix into dispersion-prone (node 1), crusting-prone (node 2), and unlikely to crust or disperse (node 3). Soil samples with particulate organic carbon (*POC*) less than 0.40 % would be classified into category 1 or 2, as the lack of *POC* is found to be ineffective in retarding their slaking and dispersion, resulting in a soil crust. The suppression of aggregate dispersion observed for the samples in category 2 appears to be influenced by the concentration of exchangeable Na^+, and from this it is suggested that and *ESP* of < 2.5 would decrease the probability of slaked aggregates subsequently dispersing. Regarding the samples with *POC* greater than 0.40 %, it is observed that the interaction with clay contents less then 50 % results in an allocation to category 3. The rationale offered is that smaller clay contents enhanced the ability of the organic matter to enmesh the aggregates, retarding their slaking and minimizing their potential to form a crust. The lesser degree of dispersion observed for samples in category 2 compared to 3 are attributed to the presence of *TIC* and a tentative value of 0.15 % is therefore included as a distinguishing criterion.

From both the classification trees presented it can be seen that the interrelationships between influential soil properties result in a number of paths terminating at nodes that characterise the surface soil structural stability. Regarding soil excessive slaking resulting in surface crusting it appears that the interaction between clay content, particulate organic carbon content and exchangeable sodium are most influential, whereas interactions between clay content, exchangeable cations and total inorganic carbon influence dispersion. Appreciating the interrelationship demonstrated by the classification trees managers can identify the potential to ameliorate soil surface problems and infer how the resulting changes in the soil properties will interact with others affecting soil surface conditions.

Conclusion

The affect that the interrelationships between influential soil properties have on soil factors is illustrated using surface structural stability as an example. This is demonstrated using a classification tree approach, which enables the interrelationships of several influential properties to be observed simultaneously. The interrelationships presented in the classification trees demonstrate that no one property can account for changes in surface soil structure and, that the significance of each soil property will depend on others. It should be noted that the critical values presented in the classification trees are tentative, being based on a small data set, and would be refined by soil additional soil stability analysis from cotton-growing areas.

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