Visual Soil Assessment: A Management Tool For Dairy Farmers

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Introduction

The economic and environmental sustainability of dairy farms is significantly affected by soil quality. The loss of soil structure by pugging under intensive grazing creates poorly aerated and water-logged soils that restrict root growth and vigour. This markedly reduces pasture production (Betteridge *et al.* 2002; Drewry *et al.* 2002; Horne & Tillman 1984; Ward & Greenwood 2002; Pande *et al.* 2002; Nicholas *et al.* 2003), tiller density (Pande *et al.* 2002; Nicholas *et al.* 2003), pasture regrowth rates (Horne & Tillman 1984; Ward & Greenwood 2002; Nicholas *et al.* 2003), pasture utilisation and stock-carrying capacity (Horne & Tillman 1984; Ward & Greenwood 2002), and reduces pasture cover (biomass) and increases the area of bare ground (Betteridge *et al.* 1999). Soil structure loss also adversely affects the quality of the pasture sward as a result of: 1) a change in the diversity of plant species in the sward due to the ingression of weeds, low fertility pasture species, and species more tolerant of water-logging and treading damage (Nicholas 1999; Shepherd 2000; Ward & Greenwood 2002); 2) a nutritional imbalance in herbage due to impaired uptake of nutrients by a stressed root system; and 3) low carbohydrate/protein ratio in the herbage resulting from lower chlorophyll content and photosynthetic potential. Increased overland and preferential flow of nutrient-rich water on and through degraded soil both increases nitrate levels in groundwater and causes accelerated eutrophication of waterways and lakes. It is therefore in the interest of farmers to know something about the quality of their soil, how to assess it, and how to manage it. To achieve this, farmers require an effective tool.

While measurement-based indicators of soil quality provide quantitative assessments, the process can be time-consuming and expensive (Shepherd & Dando 1997). The indicators used and the interpretation of measurements are also often poorly understood by the layperson. Furthermore, because farmers are not usually involved in the assessment process, 'ownership' and subsequent use of the information are generally poor. There is therefore a need for a simple, quick and easily understood method of assessing soil quality. The recognition of the need for such simple methods is widespread (Romig *et al.* 1996; King *et al*. 2000; Ditzler & Tugel 2002). Such methods should also be reliable and accurate, able to give rapid results, and be meaningful to the farmer with a minimum of training (Sarrantonio *et al.* 1996). As well as assessing the effect of farm management practices on the condition of the soil and the direction of change with time, indicators of soil quality should also provide relevant, credible, and environmentally sound information.

The effect of farm management practices, good or bad, on the soil can be obvious, even to the untrained eye. To the trained eye, the visual messages are full of information that allows effective assessment of soil quality. The trick is to train the untrained eye to recognise these same messages quickly and effectively. The Visual Soil Assessment (VSA) method was developed to allow lay people to convert the visual messages into a meaningful assessment of soil quality, and so provide a simple, effective and easily understood tool to assess soil quality semi-quantitatively, quickly and cheaply (Shepherd 2000).

Shepherd, T.G. and Park, S.C. 2003: Visual Soil Assessment: A Management Tool For Dairy Farmers. *In*: Brookes, I.M. *ed*. Proceedings of the 1st Dairy[3] Conference. Continuing Massey University Dairyfarming Annual (Volume 55) Dexcel's Ruakura Dairyfarmers' Conference, April 7–9, 2003, Rotorua. pp 111–123.
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Visual Soil Assessment

The VSA is based on the simple observation of key visual soil indicators that are diagnostic of soil quality, and is incorporated on an easy-to-use scorecard. Soil indicators are complemented by plant 'performance' indicators that link soil condition to plant performance, farm production and farm management practices. These indicators are linked to economic performance, and are underpinned by extensive research. Indicators used in the VSA have a significant influence on both pasture production and pasture quality. Information on the scorecard provides immediate feedback and allows the farmer to detect even slight changes in the impact of existing or new farming practices on the condition of the soil, and the direction of change over time. VSA provides relevant and timely information on soil performance that can be used to help establish best management practices and provides information for quality assurance programmes. It can be useful for on-farm self-regulation and self-determination, and can be used as a defensible method to demonstrate sustainable farming practices to regulatory authorities.

The VSA tool includes Soil Management Guidelines for the prevention and restoration of soil degradation and the sustainable management of farms (Shepherd *et al.* 2000). If the soil is in moderate or poor condition, the Soil Management Guidelines provide management options and recommendations to repair or ameliorate the loss of soil quality, and establish best management practices. If the soil is in good condition, the Soil Management Guidelines provide suggestions to keep it that way by preventing or minimizing soil degradation.

Three or four representative sites are selected within a paddock and their position recorded as accurately as possible, so they can be revisited for future monitoring. A spade slice of topsoil is taken from under the nearest fence line or similar undisturbed area for comparison with the sample sites. At the sampling sites, a 20-cm cube of topsoil is removed with a spade, and the VSA test carried out according to the procedure described by Shepherd (2000). The cube is dropped a maximum of three times from a height of 1 m (waist height) onto a firm base in a plastic basin, and the material is transferred to the surface of a large (75×50 cm) plastic bag and graded, the coarsest aggregates/clods graded to one end, and the finest to the other. The resulting sample provides the material for the assessment of most of the indicators. Each indicator is given a visual score (VS) of 0 (poor), 1 (moderate) or 2 (good), based on the soil condition observed when comparing the site sample with three photographs provided in the Field Guide. Scoring is flexible, so should a sample not align clearly with any one of the photographs, but sit between two, a score in between can be given, for example 0.5 or 1.5. An explanation of the scoring criteria and the importance of each indicator, accompanies each set of photographs. Because some indicators are relatively more important for soil quality than others, the VS is multiplied by a weighting factor of 1, 2 or 3 to give a VS score. The VS score of each indicator is summed to give a ranking score (a visual soil quality index), the value of which determines whether the soil has a good, moderate, or poor soil quality. The visual soil quality index is sufficiently sensitive to provide an early warning indication of any change or decline in soil quality from a baseline reference point, or from a point in time. The condition of the soil can be assessed in 15 minutes using the VSA, while the plant indicators are assessed in 5–10 minutes.

A soil quality index is gained through assessment of the soil indicators alone, as this does not require prior knowledge of the paddock history. The plant indicators require knowledge of the immediate paddock history and because of this, only those with the necessary information, or those with farming experience, will be able to complete the plant indicator scorecard. The ranking scores for soil and plant indicators are compared to provide an indication of plant performance relative to a soil quality rating. Soil scores that are significantly higher than the plant score suggests the full productive potential of the soil is not being realised. Plant scores that are significantly higher than the soil score can indicate high fertiliser inputs to counter the detrimental effects of poor soil quality on production. Comparing the soil score to the plant score encourages farmers to address why differences, if any, occur, what effect management can have on the two scores, and how the two scores could be improved.

Soil physical properties are emphasised in the VSA for several reasons:

- they are easily seen
- they have a profound influence on soil biological and chemical properties
- they have a significant impact on pasture production, pasture quality and animal health
- they have a significant impact on the productivity and input costs of a farming enterprise
- their loss can take decades to recover
- they are costly to remedy.

Field trials

The VSA was trialed at 36 sites at field days and workshops throughout the country from Warkworth to Invercargill, covering a range of soil types from different parent materials, climate, topography, and under different land uses and management practices (Shepherd *et al.* 2001). The aim was to: (1) evaluate if people, regardless of their background, could assess soil quality as effectively as an 'expert' using the VSA method; (2) establish whether it would be easy to use; and (3) ascertain whether the pitch of the VSA was suited to the potential user; and (4) determine whether VSA is a tool people would use.

Farmers can assess their soil quality as effectively as an expert using the VSA method

Field trials indicate farmers are able to assess the condition of their soil with a similar accuracy to an expert. The VSA score at each site, as ranked by an expert, usually fell well within the standard deviation of the mean of the lay person's assessment, and the two scores were often very close (Figure 1). The results also indicate strong agreement among farmers in assessing whether soils had a good, moderate or poor soil-quality ranking. The coefficient of variation in assigning a ranking score to each soil ranged from 0.05 to 0.24, with a mean of 0.12.

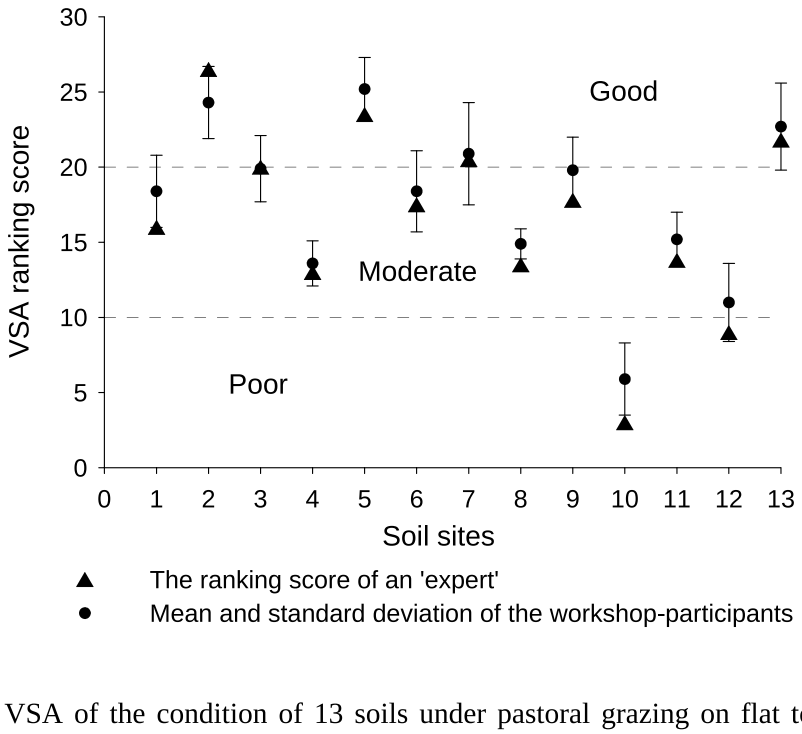


Figure 1 VSA of the condition of 13 soils under pastoral grazing on flat to rolling country – A comparison of expert and workshop participant rankings.

The VSA is easy to use

VSA was found easy to use by 85–100% of workshop participants, including 92% of farmers (Figure 2).

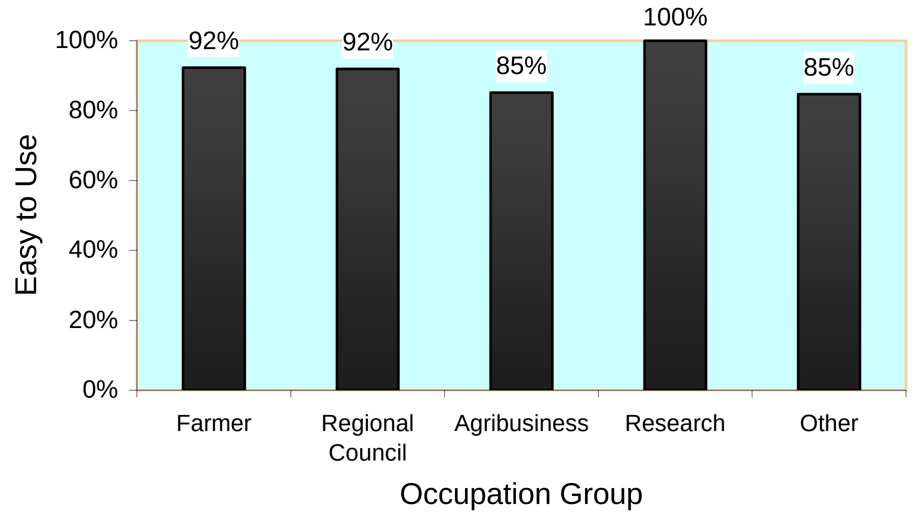


Figure 2 Workshop-participants opinion on how easy the VSA is to use.

Uptake by farmers

The technical pitch of VSA satisfied 82–97% of workshop participants, including 95% of farmers (Figure 3). Eighty seven to 100% of participants would use the VSA method to help them assess the condition of their soil, including 92% of farmers (Figure 4).

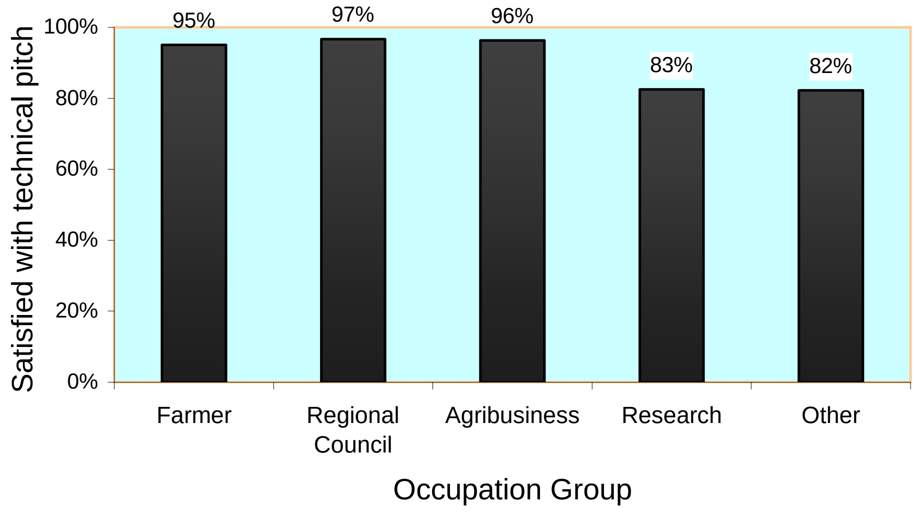


Figure 3 User satisfaction with the technical pitch of VSA.

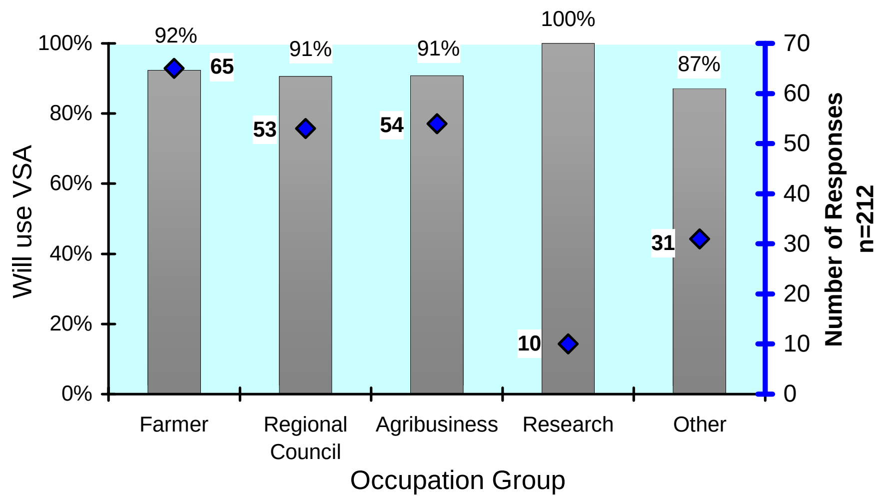


Figure 4 Percentage of workshop-participants indicating they will use the VSA.

VSA can be used anywhere

The interpretation of the visual indicators used in the VSA is generic and, as such, has the major advantage of making the VSA independent of soil type. That is, while soil type can significantly influence the VSA score, the interpretation of each indicator is not soil-type dependent. For example, the development of massive large clods with grey mottles or grey matrix colours in a topsoil that is normally dark brown, friable, and mottle-free with a well-developed structure, demonstrates the soil has become degraded and poorly aerated due to water logging and oxygen depletion. This interpretation holds regardless of soil type. This generic relationship does not hold for many indicators of soil quality and soil properties not related directly to VSA scores. The VSA can therefore be used by farmers regardless of where they are and what their soil types are.

VSA provides a reliable assessment of soil quality

The indicators used in the VSA address issues fundamental in assessing the condition of a soil, i.e. the ability of the soil to provide plants both with air, water and nutrients, and also with a rooting medium for growth and physical support. They are based on fundamental principles and processes of soil science, and can in some instances provide a more reliable indication of soil conditions that predominate throughout the year than can measured values. For example, regardless of whether water and air permeability and oxygen diffusion rates are low or high at the particular time of measurement, a soil that has strongly developed gleyed features with blue/grey matrix soil colours, demonstrates it is poorly aerated with very low redox potentials for a significant part of the year. This can only happen if the soil is saturated for a significant part of the year, or has become so degraded that the diffusion of oxygen, air and water is extremely slow, and well below the critical limits for plant growth. In contrast, many soil physical measurements are dependent on the soil type, the time of year the sample was taken for analysis, the nature of the season, the soil water content, the sampling depth, and the instrumentation and laboratory methodology used. Hydraulic conductivity, air permeability and bulk density, for example, can show high temporal dependency under a given land use. Observed morphological properties can therefore provide a reliable indication of the predominant long-term soil characteristics.

Relationship of VSA scores to measured properties

VSA indices are closely related to a number of key measured soil properties (Shepherd *et al.* 2002). The soil structure score is strongly related to the dry aggregate-size distribution, saturated hydraulic conductivity (Ksat) and air permeability, moderately related to macroporosity and bulk density, and weakly related to aggregate stability (Table 1). The soil porosity assessment is strongly related to dry aggregate-size distribution and macroporosity and weakly related to bulk density. The mottles score is weakly related to macroporosity. Dry aggregate-size distribution and macroporosity are diagnostic of the soil structure condition, while saturated hydraulic conductivity provides an indication of the likelihood the soil will become water-logged and susceptible to pugging during prolonged wet periods. Air permeability indicates the ability of the soil to 'breathe', permitting air and oxygen to enter the soil, and gases produced by plant roots and respiring soil organisms, to escape. Soil mottles provide a very sensitive indicator of the overall aeration status of the soil.

Table 1 Relationship between VSA indices and measured soil properties

VSA indices	Measured soil properties	Coefficient of determination (r^2)	*P*-value *(Probability)*	Relationship
Structure	Dry aggregate-size distribution	0.87	<0.001	Strong
Structure	Ksat	0.86	<0.001	Strong
Structure	Air permeability	0.80	<0.001	Strong
Structure	Macroporosity	0.69	<0.001	Moderate
Structure	Bulk density	0.64	<0.001	Moderate
Structure	Aggregate stability	0.58	<0.01	Weak
Porosity	Dry aggregate-size distribution	0.83	<0.001	Strong
Porosity	Macroporosity	0.79	<0.001	Strong
Porosity	Bulk density	0.51	<0.001	Weak
Mottles	Macroporosity	0.47	<0.001	Weak

The close relationship between VSA scores and measured soil properties demonstrates we can see what we measure. Examples of four of these relationships are given in Figures 5–8.

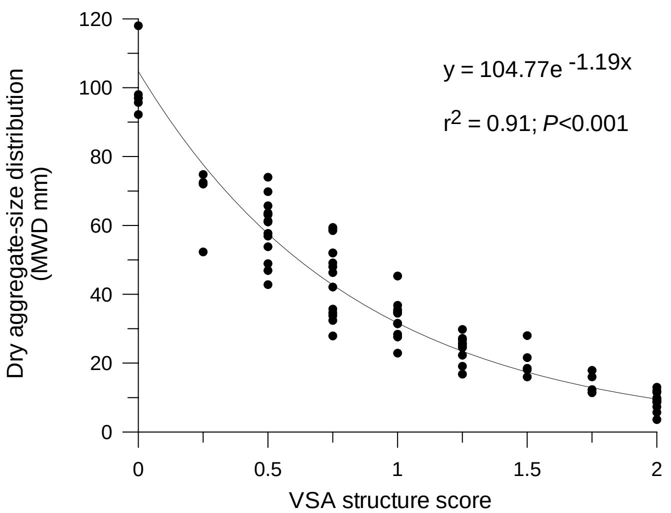


Figure 5 Relationship between the VSA structure score and the mean weight diameter of the dry aggregate-size distribution.

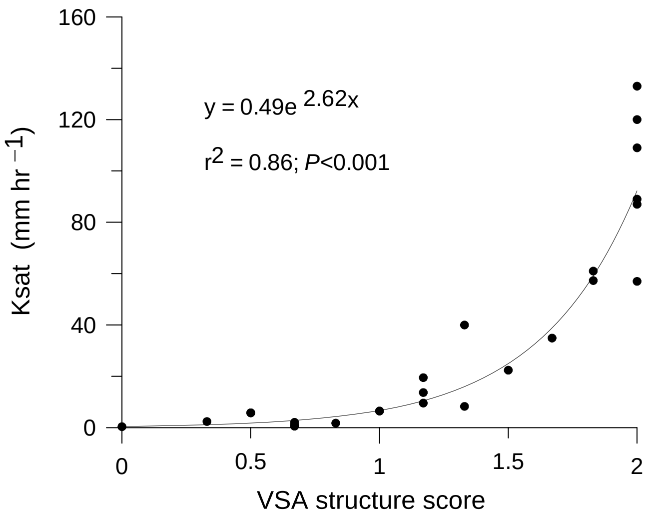


Figure 6 Relationship between the VSA structure score and saturated hydraulic conductivity.

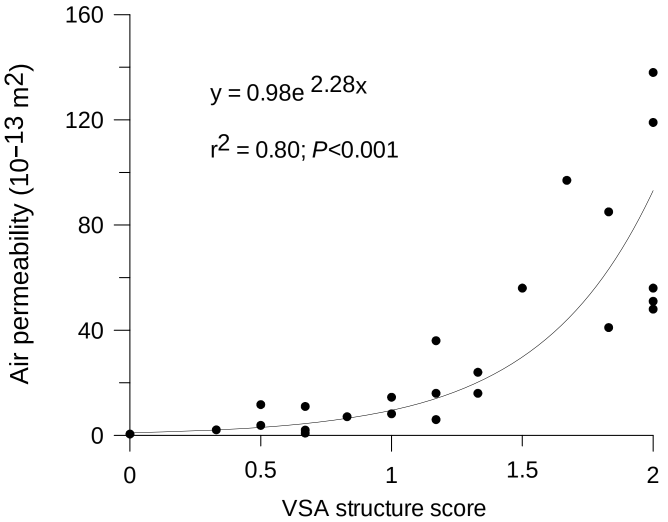


Figure 7 Relationship between the VSA structure score and air permeability.

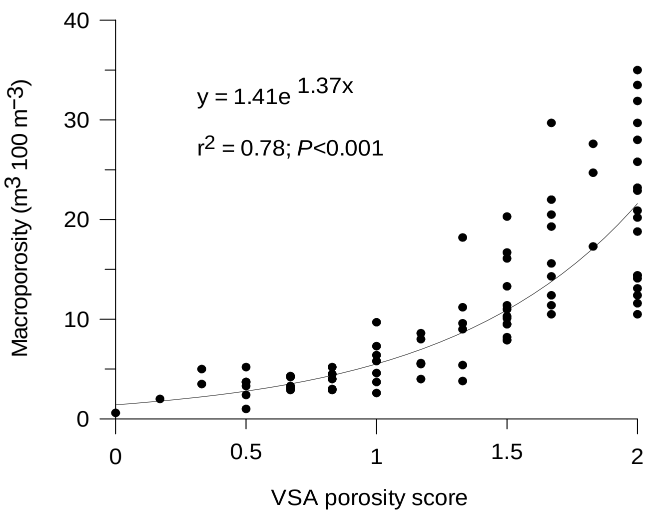
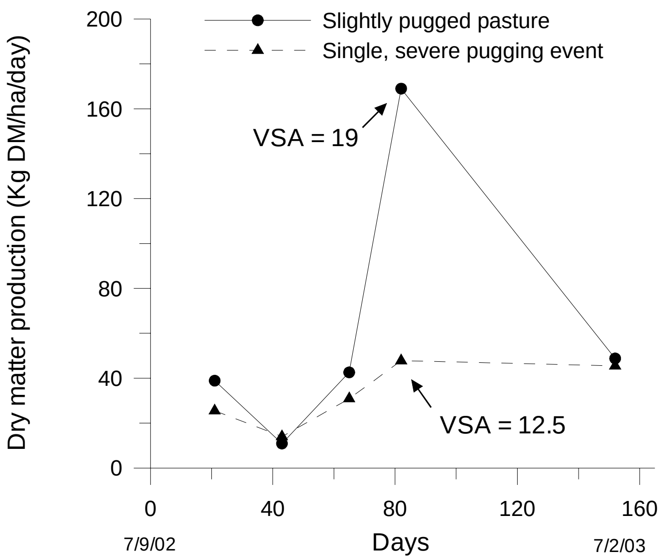


Figure 8 Relationship between the VSA porosity score and macroporosity.

A VSA structure and porosity score of 1, for example, indicates soil structure is dominated by very large, compact clods, a result of severe pugging damage (Figures 5 & 8). Such a score would also indicate the soil is poorly aerated due to a slow air permeability (Figure 7). It would be liable to become waterlogged and easily pugged for much of the winter as a result of slow hydraulic conductivity (Figure 6). Such a soil provides a hostile environment for pasture growth, and pasture quality is significantly impaired. A VSA structure and porosity score of 6 indicates the soil has a dominant porous and fine aggregate structure, with no significant clodding. Such a score would also indicate the soil is well aerated with a rapid air permeability, and due to a moderate to rapid hydraulic conductivity, would only be susceptible to waterlogging and pugging for brief periods. Soils with these properties provide an ideal physical environment for quality pasture growth. Much can therefore be derived and inferred from VSA indices.

VSA scores and their economic significance

While an index of soil quality is important, it is of limited interest if it has little or no economic significance. Soils in good condition (with VSA scores >20) have excellent pasture production, composition and utilisation, and production costs are low provided climatic conditions, soil moisture, soil fertility, grazing management, pest and plant diseases, etc., are non-limiting. Soils in moderate condition (with a VSA score of 10–20) can maintain acceptable gross profit margins. If the score falls much below 15, pasture production and pasture cover begin to decrease significantly, particularly in marginal and poor seasons. Dry matter production for example, fell by 13 kg DM/ha/day (or 400 kg DM/ha/month) when VSA scores dropped from 19 to 12½ after a single severe pugging event, and took 5½ months to recover (Figure 9). There was also a change in sward composition. Pasture biomass also declined by 35–75% on soils with VSA scores of 7–13 after a single severe pugging event. (Figure 10). After four months recovery, pasture biomass was still 20–25% less than on soils with VSA scores of 16–17.



Sward composition

	Slightly pugged	Pugged
% Grass	81.8	70.9
% Legume	6.7	7.7
% Weed	0.3	1.2
% Dead	22	9.3

Figure 9 Dry matter production and sward composition on slightly pugged pasture, and after a single severe pugging event.

Moderate pugging commonly gives rise to a loss of 200 kg DM/ha/month (or 13 kg milk solids/ha/month), and can take several months to recover to normal pasture production levels (P.L. Singleton, pers. comm.). Moderately pugged soils often have a VSA score of 15, and pasture species show a range of tolerances to waterlogging and stock treading, weeds are also common.

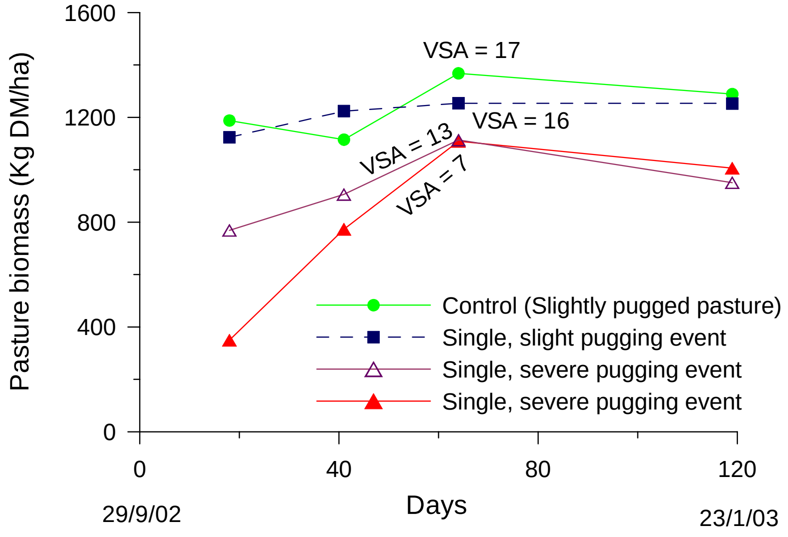
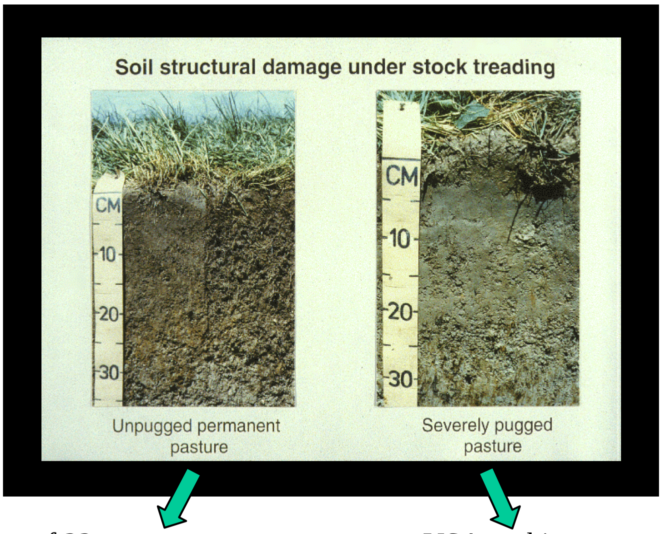


Figure 10 Pasture biomass at pre-grazing on a slightly pugged pasture, after a single slight pugging event, and after a single severe pugging event on two pastures.

Soils in poor condition (with a VSA score of less than 10) have poor pasture production and poor pasture quality. Losses in excess of 400 kg DM/ha/month (or 27 kg milk solids/ha/month) can occur, and production costs can be high. Pastures are often dominated by species more tolerant of poor aeration and waterlogging due to pugging; by species such as ryegrass, that are more tolerant of stock treading; and by species such as white clover that quickly colonise bare ground created by severe treading. Weeds are very common. The nutritional value of the herbage is poor due partly to the impaired uptake of nutrients by a stressed root system, partly to the loss of pasture species diversity, and partly to the presence of old residual herbage. As a subsequent result of selective grazing, only 20% of the pasture is utilised (Figure 11). This results in a 55% decline in milk solid production, and equates to a loss of 71 kg milk solids/ha, or $256/ha, assuming a payout of $3.60 per kg milk solid. Pasture biomass may be comparable to that on soils in good condition, but is a function of poor utilisation.

Figure 11 VSA ranking scores, spring pasture biomass and utilisation on an unpugged and severely pugged dairy pasture.



VSA ranking score of 22
Pasture biomass = 4850 kg DM/ha
Pasture utilisation = 1950 kg DM/ha (or 40%), producing 130 kg MS/ha or $468/ha

VSA ranking score of 4
Pasture biomass = 4230 kg DM/ha
Pasture utilisation = 880 kg DM/ha (or 20%), producing 59 kg MS/ha or $212/ha

High amounts of 'conventional' fertilisers are often applied to offset the effect of pugging on pasture production, and to increase the carrying capacity of the farm. The high nutrient levels and subsequent rapid growth of the pasture gives rise to high nitrate nitrogen levels and high protein/carbohydrate ratios in the herbage (Shingfield *et al.* 2001). The metabolisable energy of the pasture is reduced, with a subsequent reduction in energy levels, body condition, live-weight and reproductive function of stock (Butler & Smith 1989; Spicer *et al.* 1990; Lucy *et al.* 1991; Beever *et al.* 2001). Digestible dry matter intake is also decreased, with reduced milk yield and a decreased efficiency of utilisation in the rumen, resulting in less efficient use of feed N and increased N excretion (Miller *et al.* 2001; Shingfield *et al.* 2001). High nitrogen/protein-rich diets can induce metabolic and animal health problems, including high N levels in the blood resulting in nitrate toxaemia and infertility (Eldon *et al.* 1988). Such a diet also gives rise to high urea and protein levels in milk.

The addition of high amounts of 'conventional' fertilisers also decreases the biological life of the soil (Waipara & Torp 2000; Waipara *et al.* 2002). Soil biota promote soil fertility, nutrient cycling, soil structure, soil aeration, and filter soil-borne pathogens. Soil biological life is the 'engine room' of the soil, and impacts in a very significant way on the economic performance and long-term sustainability of a farm. As soil life becomes increasingly diminished, farmers have become further reliant on 'conventional' fertilisers to maintain production. Farmers need to manage their farms so as to maintain and, preferably, promote the biological life of the soil. 'Oiling' the engine room of the farm can be done by: 1) applying appropriate amounts of conditioner (or 'smart') fertilisers and other soil additives including compost, green manures, farm manures and farm effluent that act to stimulate rather than retard soil biological life; and 2) maintaining good soil aeration, minimising treading damage, and preparing pastures in advance for grazing under wet conditions. In so doing, medium- and long-term production costs can be maintained at low levels while farm production can be sustained at high levels.

Aim to keep your VSA score above 15. Should it fall below 15, alarm bells should start ringing to modify or tweak management practices: *healthy soils, healthy plants, healthy animals*.

Conclusions

- VSA provides farmers with a simple tool to assess and monitor effectively the condition of their soil quickly and cheaply; and the results are immediate
- The VSA allows farmers to assess the condition of their soil within 15 minutes, and the condition of their pasture within 10 minutes
- The VSA tool is able to detect slight changes in the impact of existing or new farming practices on the condition of the soil, and the scorecard provides a valuable reference document for tracking the effect of management, and the direction of change with time
- Indicators used in the VSA have a significant influence on both pasture production and pasture quality
- The soil indicators are supported by plant 'performance' indicators that link soil condition to farm production, farm management practices and ultimately farm profitability
- The soil and plant scorecards provide a focal point for discussion of the relationship between the VSA score, farm productivity and farm management
- VSA provides relevant and timely information on soil performance that can be used to help establish and evaluate, the effectiveness of best management practices and provides information for quality assurance programmes. As such, it can be useful for on-farm self-regulation and self-determination
- VSA can be used as a defensible method to demonstrate sustainable farm management practices to regulatory authorities
- The indicators are closely correlated to many measured soil properties, demonstrating that you can see what you measure
- Because the interpretation of the visual indicators used in the VSA is independent of soil type, it can be used anywhere
- VSA can be used by anyone – farmers with little or no understanding of soil science can use VSA as effectively as an expert to assess and monitor the condition of their underground economy
- Farmers find VSA easy to use and pitched at the right level

- Because of its simplicity and ease of use, the VSA is a useful educational and vocational training tool, encouraging a better understanding of soil quality and its relationship to plant growth, and its fundamental importance to sustainable farm management
- 'Oil' the engine room of your farm by maintaining good soil aeration and applying conditioner ('smart') fertilisers and products that stimulate rather than retard soil biological life.

Acknowledgements

The VSA programme was funded by the Manawatu-Wanganui, Hawke's Bay and Wellington Regional Councils, and by the Ministry for the Environment and MAF Policy. Pasture production data and pasture composition for Figures 9 and 10 were provided by Keith Betteridge, AgResearch, Grasslands.

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