THE OCCURRENCE AND CAUSES OF PASTURE PULLING UNDER DAIRY FARMING ON PUMICE SOILS

A thesis
submitted in partial fulfilment
of the requirements for the degree
of
Master of Science (Research)
in
Earth Sciences
at
The University of Waikato
by
Emma Rosiland Bagley

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

2015

Abstract

The occurrence, and causes, of pasture pulling under dairy farming on Orthic Pumice Soils (Typic Udivitrands) in the central North Island of New Zealand was investigated. Pasture pulling occurs on Pumice Soils, where dairy cows pull clumps of pasture from the soil, thus diminishing pasture production. The overall objective of this study was to investigate the occurrence, and establish the causes, of pasture pulling under dairy farming on Orthic Pumice Soil in the Central North Island, New Zealand.

Fifteen paddocks containing pasture of differing ages were investigated at Pouakani dairy farm near Mangakino. Soil profile descriptions were undertaken, and samples were taken seasonally to monitor root depth and density, soil macrofauna, soil dry bulk density, and penetration resistance. Pasture pulling was monitored every 3 weeks by recording the number and size of pulls in a 4 m^2 quadrant at five points equally spaced along a transect in 15 paddocks.

Pasture pulling was recorded in all paddocks and occurred throughout the year, but was most common during the late summer and autumn. Up to 80 % of the root biomass was in the 0-5 cm depth. The 5-10 cm depth generally showed increased compaction with higher soil dry bulk density and penetration resistance then the surface soil. Pastures in isolated clumps were more commonly pulled than more evenly spread pastures. There was an interaction between pasture age and size of pulls, with more medium and large sized pulls in the younger (1-3 year old) pastures. Although anecdotal evidence reports worse pulling in younger pastures, we did not find strong evidence for that assertion.

Pasture pulling in 2014 at Pouakani dairy farm was not more obviously impacted by insects. Grass population numbers were uniformly low, and black beetle was rarely seen.

Perennial ryegrass was dominant in all paddocks. The paddocks with older, more established pastures contained a higher proportion of other grass species and weeds. Only grass was pulled, other species such as clover, chicory and weeds were not pulled by grazing stock. A pasture pulling index, created to account for the size distribution of the pulls, was more effective at illustrating the seasonal trends associated with pasture pulling than the mean total pulls per quadrat.

Overall, the pasture pulling was not severe at Pouakani Dairy farms in 2014. This study has not discovered one sole cause of pasture pulling at Pouakani dairy farms, but has identified a number of soil characteristics that may be contributing, including; limited rooting depth, low root density in the 5-10 cm depth, increased compaction with depth, less cohesive soil when it has low moisture, and the incidence of pasture growing in clumps.

Acknowledgements

There are several people who have helped me significantly with this thesis, who without their support, would not have been possible. First of all I would like to thank my supervisors Dr Megan Balks and Dr Gina Lucci, for their support and guidance, keeping me in the right direction and answering all my questions. I would like to thank the generosity of the C Alma Baker Trust, Dairy NZ, and the Broad Memorial fund for providing funding for this project.

I would like to acknowledge everyone at AgResearch for their advice, support, and letting me pick their brain on various aspects of this thesis, and enabling me to use the lab and other resources. A special thanks goes to Harold Henderson who helped me significantly with analysing my data using GenStat. I would like to thank the staff at the University of Waikato for helping me organise field equipment, the use of the lab, and other technical support. A special thanks goes to the Wairarapa Moana Incorporation, in particular Chris & Isaac Berry, David March and the farm managers for allowing me to conduct research on the farms, and helping with paddock selection and paddock history.

To my friends and family, thank you for encouraging me and providing an ample distraction when necessary. A big thanks to my fellow students, especially Olivia, who made life easier knowing that they were on the same journey as I was. A special thanks to Adam, for his support, and giving me one final push to complete this thesis. On a final note, this thesis is dedicated to my parents, Graham and Vicky, whom without their love and support in many different forms, including help with field sampling, this would not have been possible.

Table of Contents

List of Tables

List of Figures

Chapter 1 - General Introduction

1.1 Background and motivation

Pasture pulling is an issue of concern in the central North Island, notably in Pumice soils. Pasture pulling occurs where grazing livestock pull whole clumps of pasture from the soil. Pasture pulling can diminish pasture production, allow weed invasion, and result in the pasture becoming less palatable to livestock. The mechanisms and causes of pasture pulling are poorly understood, but may be catalysed by a number of factors, including combinations of: soil compaction, hard pans, chemical enrichment or depletion, nutrient availability, damage to plant roots by grass grubs, pasture composition, weather and soil moisture conditions, and shallow rooting depths.

My research was undertaken at Pouakani dairy farms, located near Mangakino in South Waikato (Figure 1.1), which is owned by the Wairarapa Moana Incorporation.

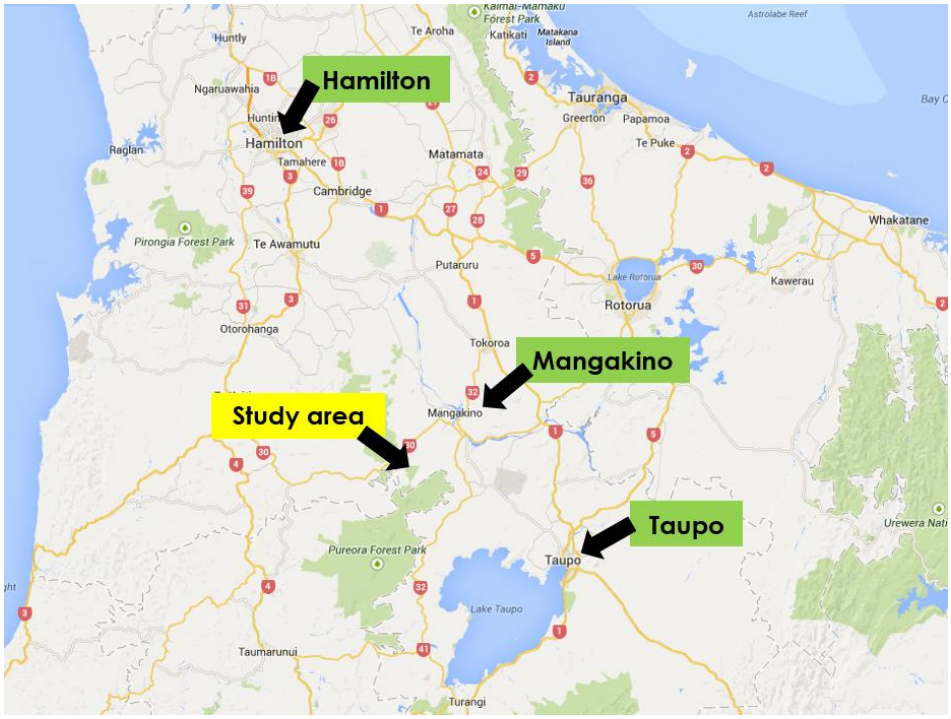


Figure 1.1: The field area was approximately 10 km from Mangakino in the Central North Island of New Zealand (Underlying map from Google, 2014).

The Wairarapa Moana Incorporation owns 10,695 ha of land which was previously native bush and scrub, and has since been converted to a dairy unit (2,870 ha), a sheep and beef unit (1,325 ha), and the remaining 6,500 ha a forestry block. The dairy unit was previously in sheep and beef, then gradually converted over the last 30 years. Pasture pulling (Figure 1.2) has been a problem on the farms (especially on the dairy unit) for several years, and reported by farm managers to be most prominent in relatively young pasture (1-2 years old). The dairy farms investigated were all situated on Pumice Soil, which is very friable, and exhibits moderate soil strength.

Figure 1.2: Pasture "pulled" from the soil with minimal force.

1.2 Objectives

The overall purpose of my thesis was to investigate the occurrence, and establish the causes, of pasture pulling under dairy farming on Orthic Pumice Soil in the Central North Island, New Zealand.

I have a series of alternative hypotheses:

a) Pasture pulling occurs where soil compaction is limiting the downward expansion of roots.
b) Pasture pulling occurs when there is severe damage to roots as a result of grass grub infestation.
c) More pasture pulling occurs when soil has lower moisture content.
d) Younger pastures are more prone to pasture pulling.

My specific objectives were to:

(1) Identify and monitor paddocks that consist of one year old pasture, and compare them with paddocks which contain established pasture (greater than four years old) which was not expected to pull, as well as two and three year old paddocks (addresses hypothesis d).

(2) Monitor selected sites to examine seasonal changes, measuring parameters such as weather and soil moisture conditions, pasture composition, rooting depth, and presence of grass grub or black beetle (addresses hypotheses b, c and d).

(3) Undertake laboratory analyses to investigate soil chemical and physical properties to establish if they change seasonally, or are correlated with occurrence of pasture pulling (addresses hypotheses a, c and d).

(4) Use statistical analyses to try and identify the major factors that contribute to the occurrence of pasture pulling (addressing all alternative hypotheses).

Chapter 2 - Literature Review

2.1 Introduction

The mechanisms and causes of pasture pulling are poorly understood. This chapter reviews literature surrounding pasture pulling, and the conditions that lead to pasture pulling. It also highlights studies on pumice soils. This literature review defines pasture pulling and its occurrence and the conditions that lead to pasture pulling. Soil physical conditions (soil type, compaction and root penetration), chemical conditions (nutrient availability and chemical enrichment), and biological conditions (pasture species variation and soil biology) are discussed. Information on different pasture sowing methods and their influence on pasture persistence and susceptibility to pulling is included.

2.2 Pasture pulling definition and its occurrence

Pasture pulling can be defined as the physical removal of clumps of pasture plants and some roots, from the sward by cows during grazing (Thom *et al.*, 2003). Pasture pulling is of concern to farmers due to the potential to reduce sward productivity and persistence, and the increased likelihood of weed invasion (Crush *et al.*, 2002; Thom *et al.*, 2003). Pasture pulling is known to be at its most prominent during the late summer and autumn (February-April) (Tallowin, 1985; Blank & Olson, 1988; Houlbrooke, 1996).

2.3 The influence of soil properties on pasture pulling

2.3.1 Soil type

The soil type is an important factor to be considered when investigating the causes of pasture pulling. Pasture pulling can be influenced by the *in situ* strength of the soil and its ability to resist tensile strain. Houlbrooke (1996) researched pasture pulling on three different soil types in the Hamilton basin. Trends showed that the Te Kowhai silt loam (Gley soil), which had greatest soil strength, suffered the least pulling compared to the

Te Rapa peaty silt loam, which had the lowest soil strength and the most pasture pulling. Thom *et al.* (1996) also found that a higher level of pasture pulling occurred on peat soils rather than on silt loam soil. Thom *et al.* (2003) reported that leaf width, and therefore leaf strength (which can influence the likelihood of a pasture being pulled) was greater when pasture plants were grown on a Te Kowhai silt loam rather than the Te Rapa peaty silt loam. This is an example of the ability of ryegrass lines to change their morphology in response to the environment they are growing in (Thom *et al.*, 2003).

2.3.2 Soil moisture

Soil moisture changes may influence pasture pulling. A study conducted by Thom *et al.* (1998) compared the herbage production, persistence and crown rust resistance on different ryegrass varieties. All ryegrass varieties pulled the worst during year 3 of the trial, which was also when the plants were under water stress due to an extended dry period which occurred from late spring to early autumn (Thom *et al.*, 1998). A 3 - 4 fold increase in pulling was observed during grazing in the dry period compared with years 1 and 2. Bahmani *et al.* (2001) and Thom *et al.* (1996) also reported that low soil moisture levels can lead to increased ryegrass pulling. In contrast, Houlbrooke (1996), suggested that pasture pulling in the late summer and throughout autumn occurred when soil moisture begins to increase.

2.3.3 Pumice soil properties

Pumice Soils (NZ soil classification, equivalent to Vitrands in Soil Taxonomy) are derived from sandy or pumiceous volcanic ashes, which are relatively young (Hewitt, 2010). Pumice soils occur predominantly in the central North Island, and cover 7 % of New Zealand (Hewitt, 2010; Landcare Research, 2014). Pumice soils are formed on weakly weathered, coarse textured, glassy and pumiceous rhyolitic deposits derived from the Taupo eruption in c. 232 AD ± 15 and the Kaharoa eruption in c. 1314 AD ± 12 (Lowe & Palmer, 2005). Pumice Soils generally have weak to very weak soil strength, and often have apedal earthy or single grain pedality (Hewitt, 2010). Pumice soils generally

contain a low (less than 10 %) content of clay (Landcare Research, 2014), and typically contain allophane (Hewitt, 2010). Some soil layers may be welded, which may express greater soil strength. Pumice Soils can provide a deep rooting medium (Landcare Research, 2014), except in welded flow tephra's which can act as a compacted layer (Hewitt, 2010). Pumice Soils are sensitive, meaning they can undergo a sudden loss of strength (Selby & Hodder, 1993), resistant to pugging, and can be susceptible to compaction on loading (Hewitt, 2010). Pumice Soils also contain low reserves of major nutrient elements such as sulphur, nitrogen, magnesium and phosphorus. Trace elements such as copper, cobalt, boron and selenium are likely to be deficient (Lowe & Palmer, 2005; Hewitt, 2010; Landcare Research, 2014).

The vesicular nature of pumice strongly influences the density and porosity of pumice soils, which have high macroporosity (Landcare Research, 2014). Pumice soils have low bulk densities, generally less than 1.0 g/ml throughout the profile (Read, 1974). Low soil dry bulk density, and easy entrainment of pumice particles due to their coarse textures, makes Pumice Soils easily eroded, therefore gully erosion is prominent. Pumice Soils are susceptible to droughts (Selby & Hosking, 1973). Because of the coarse texture and susceptibility to droughts earthworm populations are low in pumice soils (Landcare Research, 2014). The sandy gravel textures of Pumice Soil enables the soil to be very porous and drain rapidly, which results in low moisture levels (Molloy *et al.*, 1998).

2.4 The influence of soil compaction, soil strength, and root penetration on pasture pulling

2.4.1 Soil compaction

Soil compaction is a common problem under grazing both in New Zealand and overseas, and can be influenced by soil type, soil moisture conditions, and stocking rate. Soil compaction can be defined as a change in soil volume leading to increased soil dry bulk density, reducing the air volume and causing closer packing of the soil particles (Hillel, 1980). Soil

compaction can be caused when dairy cattle tread wet soil, resulting in decreases in macroporosity, soil hydraulic conductivity, and permeability (Drewry *et al.*, 2008; Crush & Thom, 2011). Drewry *et al.* (2004), reported that soil is most susceptible to compaction and deformation in wet spring conditions. Soil compaction can contribute to reduced plant and pasture cover, and contribute to erosion and surface runoff (Drewry *et al.*, 2008).

Measuring the soil dry bulk density can give an indication of the level of compaction in a soil, as soil dry bulk density includes the pore space in the soil (McLaren & Cameron, 1996). The increase in soil dry bulk density can also restrict root development (Harrison *et al.*, 1994). The harmful effects of soil compaction can last for many months. The effects of soil compaction are most apparent at the 5-10 cm soil depth (Drewry *et al.*, 2004; Crush & Thom, 2011).

2.4.2 Soil Strength

Soil strength is defined by McLaren and Cameron (1996) as “the ability of soil to resist a force without shearing”. Volcanic ash soils have lower cohesion than predominately clay soils, and therefore are more prone to erosion (McLaren & Cameron, 1996). Soil strength can be indirectly measured using a penetrometer, which measures the force required to push the tip of the penetrometer into the soil. It is useful for measuring the resistance of a soil to root penetration (McLaren & Cameron, 1996). Penetration resistance is strongly dependant on the water content of the soil (McLaren & Cameron, 1996).

2.4.3 Root penetration

Plant root systems are an important factor that are intimately involved in pasture pulling. Plant root systems not only absorb water and nutrients from the soil, but also act as an anchor to prevent the plant from being uprooted. Uprooting can be associated with root systems that undergo restricted growth due to a shallow compacted layer of soil (Crush *et al.*, 2002). Ennos (1990) stated that the pull-out resistance of the roots is directly proportional to the length of roots. It is better to have many thin

roots as opposed to minimal tap roots, as many thin roots would use more soil material for anchorage than single tap roots (Ennos, 1990).

Severe cases of ryegrass pulling have been observed in the Horotiu soil under dairy pastures in the Waikato region, resulting in re-sown pasture (Crush *et al.*, 2002). In the re-sown pastures, ryegrass roots were predominately found in the top 50 mm of soil, with no roots below 200 mm. Crush *et al.* (2002) suggested that a deeper rooting system would reduce pasture pulling, increase access to moisture as the topsoil dries, and increase nutrient uptake and thus reduce nitrate leaching.

The penetration resistance of a soil can determine variations in root development. Increased penetration resistance in compacted soil can reduce the downward growth of roots (Crush & Thom, 2011; Becel *et al.*, 2012). Houlbrooke (1996) observed that pasture pulling may be related to increased soil compaction measured by penetration resistance between 7 and 10.5 cm depth, as the clumps appear to be pulled at this depth, and it is possible that the compacted layer acts as a barrier to root growth. The growth of ryegrasses in tephra soils decreased as the soil dry bulk density increased from 0.9 to 1.0 mg/m^3, with a concurrent increase in penetration resistance of 30 %, and root length decreased by up to 50 % between the range of soil dry bulk densities measured (Houlbrooke *et al.*, 1997).

Compact zones with high soil dry bulk density can restrict root penetration and the radial growth of roots (Unger & Kaspar, 1994; Cook *et al.*, 1996). Ryegrass has some difficulty growing roots through a compacted soil layer as it possesses fine roots (Crush & Thom, 2011). Cook *et al.* (1996) found that impedance of the soil negatively affected the growth rate and, therefore, final length of roots.

2.4.4 Subsoiling

Subsoiling is defined as the loosening of compacted soil layers (Harrison *et al.*, 1994). Subsoiling can be used to break up a compacted soil layer and enable; the downward growth of roots, increased soil macroporosity and air permeability, and reduced soil dry bulk density (Crush & Thom, 2011). Subsoiling significantly improved soil physical properties such as decreasing soil dry bulk density, and increasing macroporosity and air permeability in a Pallic Soil in Southland (Drewry *et al.*, 2000). The effects were evident up to 2.5 years after the treatment, however re-compaction of the upper 18 cm of soil profile occurred.

The effects of subsoiling on an 8 year old dryland pasture soil in Canterbury, New Zealand, led to significantly greater root lengths and a higher percentage of roots penetrating below the 30 cm depth. Subsoiling reduced soil bulk density by 11 % and increased porosity compared to unloosened soil, which enabled pasture roots to penetrate compacted horizons which couldn't be penetrated before the subsoiling (Harrison *et al.*, 1994). Harrison *et al.* (1994) also reported that subsoiling also resulted in a significant increase in pasture production in the first 3 months after subsoiling.

2.5 Chemical conditions that influence pasture pulling

2.5.1 Aluminium solubility

Aluminium toxicity in soils can impede the development of roots, which could enable the pasture to be pulled more readily from the soil. Aluminium toxicity is influenced by the pH, in which a lower pH increases the solubility of aluminium. A pH of <5 can impede plant development (Álvarez *et al.*, 2005). Aluminium availability in soils can cause reduced root elongation, and at high aluminium levels, death of the plant (Robson, 1989). Lateral roots are impacted more than primary roots, and can give a typical 'stubby' root appearance. A result of increased aluminium availability is that it creates an inefficient root system for absorbing nutrients and water (Robson, 1989).

2.5.2 Nutrient availability

The use of nitrogen fertilisers may affect the severity of pasture pulling (Oswalt *et al.*, 1959; Mitchell & Dickens, 1979). Nitrogen fertilisation influences the rates of growth of both stem and root tissue of pasture, with higher nitrogen fertilisation rates giving increased pasture growth, and reduced root elongation (Oswalt *et al.*, 1959). Soil sod strength decreased with increasing amounts of nitrogen available to the grass, which Mitchell and Dickens (1979) suggested may be the result of temporary salt damage to the root system. It was also suggested by Mitchell and Dickens (1979) that the strength of roots could be reduced by applications of nitrogen fertiliser as available carbohydrate was diverted from root to shoot growth.

A study conducted by Bahmani *et al.* (2001) reported that the highest pulling levels occurred when nitrogen fertiliser was applied without irrigation. However this contrasts with the findings of Thom *et al.* (2003), who reported that nitrogen fertiliser inputs did not affect clump shear strength or pulling in an experiment which investigated the pulling tolerances between two perennial ryegrass cultivars.

2.6 The influence of pasture species variation on pasture pulling

2.6.1 Variation in pasture persistence

The severity of pasture pulling can be attributed to pasture species variation, as different species can have different susceptibility to pasture pulling during grazing. Perennial ryegrass (*Lolium perenne*) is the most commonly sown pasture grass in New Zealand. Perennial ryegrass is a prolific tillering, compact grass, with shallow rooting depth and adapts to medium to high fertility soils that are well drained (White & Hodgson, 1999). Perennial ryegrass is susceptible to insect pest damage including grass grub and porina (White & Hodgson, 1999), which can contribute to pasture pulling. Italian ryegrass (*Lolium multiflorum)* is similar in appearance to perennial ryegrass, but the leaves and tillers are larger, and are very susceptible to grass grub and porina damage (White & Hodgson,

1999). Pasture species such as Tall fescue (*Festuca arundinacea*) and Phalaris (*Phalaris aquatica*), which are deep-rooted perennial grasses with large tillers, and cocksfoot (*Dactylis glomerata*) are all more tolerant of grass grub (White & Hodgson, 1999).

Cultivar differences can produce different severities of pulling. Thom *et al.* (2003) investigated the morphology and sward structural characteristics of two perennial ryegrass lines, which were showing different pulling tolerances. The first line, which was coded NZA1, pulled more than the second line, NZA3. NZA1 had higher leaf shear strength, wider leaves and lower clump shear strength than NZA3. A higher clump shear strength in NZA3 provided a better anchor for the pasture, and a smaller leaf strength and size resulted in the pasture leaves breaking off more easily, leading to reduced pulling (Thom *et al.*, 2003). Bahmani *et al.* (2001), compared the productivity of perennial ryegrasses from different ecotypes and showed that the 'Ellett' ryegrass was more prone to pulling than 'Grasslands Ruanui'. It was concluded that greater pulling in 'Ellet' was because 'Ellett' plants had more upright tillers and larger leaves, making it more accessible to dairy cows, and therefore easier to pull.

Clover additions to the pasture sward can impact on the amount of pasture pulled. Burggraaf and Thom (2000) observed that pulling was significantly reduced when white clover content was high in the sward. The white clover provided an increased resistance to pulling by increasing the forces required to remove the clumps.

2.6.2 Root biomass variation in pasture species

There are differences in the root biomass between different pastures, which may influence pasture pulling. Tall fescue is known to be a deep rooting grass and is more capable of growing roots through a compacted layer, and also have thicker roots than surface rooting types (Crush & Thom, 2011; Milne, 2011). Clark (2011) suggested that ryegrass and white clover both have shallow root systems, especially in compacted soils, which make them more susceptible to droughts, and pulling in summer.

2.7 The influence of soil fauna on pasture pulling

Soil organisms can play an important role in pasture pulling, and can have both short and long term effects. Insect damage can be intensified by other factors such as climate, soil fertility, weed invasion, and grazing animals, to severely reduce pasture persistence (Zydenbos *et al.*, 2011). Root death over summer can cause a net loss of functioning roots, resulting in shallower and weakened root systems. Shallower and weakened root systems can be worsened by root feeding organisms such as grass grub and black beetle (Milne, 2011), enabling the pasture to be pulled easily by grazing animals. Campbell *et al.* (1996) stated that invertebrates feeding on the roots of pasture enabled the pasture to be pulled more readily from the soil, creating gaps which are often filled with other grasses and weeds. Earthworms can indirectly help to improve pasture persistence by improving the soil physical quality, and increasing macropores to provide better rooting depths (McLaren & Cameron, 1996).

2.7.1 Grass grub

New Zealand Grass grub (*Costelytra zealandica*) are a major pasture pest in New Zealand. Larvae are most damaging as they feed on the roots of pasture plants during the late summer-autumn period, particularly to pastures in early establishment (East *et al.*, 1980; Patchett *et al.*, 2011; Zydenbos *et al.*, 2011).

Different pasture species display varying levels of tolerance to grass grub attack. Tall fescue pasture has a good tolerance to grass grub infestation (Prestidge *et al.*, 1985; Milne, 2011). East *et al.* (1980) investigated the effect grass grub has on the production of different pasture species and found that ryegrass and white clover suffered the greatest loss in production in autumn and winter, and that cocksfoot and prairie grasses were less affected but still suffered losses over the same period. Grass grub populations of more than 200/m^2 in the North Island pumice country 3 year old pastures caused losses of up to 44 % to pure ryegrass swards (East *et al.*, 1980). Tall fescue was very tolerant of grass grub with

production not significantly impacted. Cropping species such as Lucerne are tolerant of grass grub (Milne, 2011).

2.7.2 Earthworms

Earthworms impact on the chemical and physical quality of the soil. Earthworms feed on plant and animal matter, which is partially degraded and deposited, as earthworm casts, back into the soil. Earthworm casts are rich in micro-organisms, organic matter and plant nutrients (McLaren & Cameron, 1996; Schaetzl & Anderson, 2005). From a soil physical perspective, earthworms remove dead roots and, together with their burrowing activity, promote aeration and drainage of the soil, thus helping to improve plant growth and root penetration (McLaren & Cameron, 1996) and increase the amount of macropores (Schaetzl & Anderson, 2005). Earthworms tend to avoid sandy soils and prefer moist soils with medium textures (Schaetzl & Anderson, 2005).

2.7.3 Black beetle

Black beetle is a pasture pest that has caused considerable pasture damage throughout the Auckland and Waikato regions. Black beetle larvae feed on the roots of pasture, particularly in summer (Blank & Olson, 1988; Zydenbos *et al.*, 2011). Tunnelling by black beetle loosens the turf of ryegrass pasture and enables livestock to pull the pasture more readily from the weakened soil (Blank & Olson, 1988). If populations of black beetle are high in summer, damage to pasture is likely to be worsened by drought (Zydenbos *et al.*, 2011).

A study conducted by Blank and Olson (1988) investigated the effects black beetle had on pasture production, and compared pulling on ryegrass pastures treated with insecticide with pastures without the treatment. Plots which were insecticide-free had 10-20 % more bare ground than the insecticide-treated plots. The pasture could be readily pulled from the roots of 96 % of soil cores from the insecticide-free plots and only 6 % from the insecticide-treated plots.

2.7.4 Argentine stem weevil

Argentine stem weevil (*Listronotus bonariensis*) is a damaging pest to pasture. Adults feed off the leaves of pasture, but larvae cause the greatest damage to pasture yield as they feed on the stem, weakening plants and causing them to be more likely to be pulled by grazing cattle (Barker *et al.*, 1989; Zydenbos *et al.*, 2011). A study conducted by Prestidge *et al.* (1989) investigated the populations of Argentine stem weevil and its damage to tall fescue pastures. Pasture that had been pulled by grazing cattle had been more severely attacked by stem weevil larvae and had a higher level of tiller death than the pasture that hadn't been pulled. This may be related to crown death of the roots caused by the larvae.

2.7.5 Endophyte in pasture seed

The use of endophyte in seed has also been trialled to reduce pasture pulling. Endophyte can be defined as an organism such as fungi that form symbiotic relationships with the host plant, and can release compounds which can enhance resistance various elements, including insect damage (Wang *et al.*, 2004). In a study conducted by Kerr *et al.* (2012), the agronomic performance of a range of perennial ryegrass cultivar-endophyte combinations across different sites in New Zealand was assessed. Pasture pulling was shown with clear differences between cultivars, but did not show differences in pulling concerning endophyte strain, which contradicts Prestidge *et al.* (1989), who suggested that endophyte strain might affect plant pulling. Milne (2011) stated that there is currently no ryegrass endophyte available that provides protection from black beetle larvae, or grass grub.

2.8 The influence of pasture sowing methods on pasture pulling

Many methods are used to establish new pastures in New Zealand including cultivation, spray and direct-drill, oversowing and undersowing. Undersowing involves no seedbed preparation (cultivation or subsoiling) and is the process of direct-drilling without spraying existing pasture, and is often used to patch up pastures (Thom *et al.*, 2011). Oversowing, or broadcast sowing, is the process of broadcasting seed onto the soil

surface (Thom *et al.*, 2011). In the 1950s and 1960s undersowing became popular in New Zealand with the introduction of direct-drilling machines (Thom *et al.*, 2011). An advantage of direct drilling is better seed-to-soil contact from better control of seedling depth, but direct drilling cannot be used on steep topography. Broadcasting however, requires less machinery and can be undertaken on any topography (Schlueter & Tracy, 2012).

Research has been carried out investigating the effect sowing technique has on pasture establishment and persistence. Schlueter and Tracy (2012) showed no difference in clover establishment or persistence over 3 years when comparing broadcast and direct drilled treatments. Brock and Kane (2003) compared clover establishment via direct drilling vs broadcast sown pastures. Direct drilling in rows provided more space for the clover to grow into, however there was more access for the pasture to be overgrazed, compared to broadcast sown pastures which had a more uniform distribution of grass enabling less stock access to clover and therefore more protection while establishing.

It is important to apply special management practices to newly established pastures to help them persist. Rules such as grazing 5-7 weeks after drilling, using young stock, refraining from making silage or hay from new pastures, and not grazing new pastures after periods of stress such as prolonged dry/wet periods are recommended to prolong new pastures during the establishment year (Thom *et al.*, 2011).

2.9 Grazing

“Overgrazing” pastures, and hard grazing over summer, led to increased pasture pulling. Campbell *et al.* (1996) stated that hard grazing in summer when pastures were dry led to more ryegrass pulling, and created gaps which could be filled with unwanted pasture species and weeds. Overgrazing pastures in the summer can also lead to increased solar radiation exposure to the soil surface, resulting in high temperatures in the

upper soil layers which can be deadly to many pastures (Eerens *et al.*, 2002).

2.10 Summary and conclusions

This literature review defined pasture pulling as the physical removal of clumps of pasture plants and some roots from the sward by cows during grazing. Pasture pulling is prominent in the warmer seasons when soil moistures are lower. Soil characteristics such as soil texture and strength can influence pasture pulling. Soil compaction can lead to increased likelihood of pulling to occur, in which soil dry bulk density can be calculated to measure compaction. Subsoiling can help to reduce soil compaction. Chemical conditions in the soil such as aluminium toxicity due to low soil pH, and high nutrient availability from fertiliser additions, can cause the pasture to be more vulnerable to pulling. However, some research contradicts the effects of aluminium toxicity and high nutrient availability on pasture pulling.

Studies that research the pasture species vulnerability to persistence and pulling showed that some species are more susceptible to pulling than others. Root biomass variation in pasture species may influence pasture pulling. Soil fauna such as black beetle and grass grub have also been shown to impact on pasture plants and the likelihood of a pasture to pull. Entophyte are being developed to prevent the negative effects of soil fauna on different pastures. Pasture sowing methods influence the establishment of new pastures, and could influence vulnerability to pasture pulling. Overgrazing may also lead to increased pasture pulling.

Although there is research surrounding the variables that influence pasture pulling, notably from New Zealand, there is not a great deal of research that directly addresses the causes of pasture pulling. This thesis attempts to bridge this knowledge gap and provide a clearer understanding of the mechanisms surrounding pasture pulling in Pumice Soils under dairy farming.

Chapter 3 - Methods

3.1 Introduction

Chapter 3 describes the methods used in the investigation of the causes of pasture pulling. Soil samples were taken seasonally to establish if there were seasonal differences in various soil properties. An initial soil characterisation was conducted in conjunction with the first soil sampling, and a pasture pulling assessment was conducted every three weeks to monitor pulling. Section 3.2 describes the site and paddock selection, with the procedure used for the pasture pulling assessment defined in Section 3.3. Section 3.4 describes the methods used in the initial soil characterisation, and Section 3.5 describes the seasonal monitoring programme.

3.2 Site and paddock selection

Fifteen paddocks were selected for the investigation. In order to obtain comparable samples from the site, paddocks were chosen based on having the same soil and landscape unit, and paddocks that underwent similar management practices such as non-irrigated, non-effluent irrigated, and consistent fertiliser applications. Flat areas of the paddock were chosen to sample from. The paddocks selected had a range of pasture ages, and comprised of: four paddocks which contained one year old pasture, 7 paddocks of two to three year old pastures, and four paddocks with 4 year old or older pastures.

3.3 Pasture pulling assessment

A pasture pulling assessment was conducted on each monitored paddock every three weeks. A transect was established across each paddock. Five 2m x 2m quadrats (area 4 m^2) were spaced evenly along the transect (Figure 3.1). Within each quadrat, pasture pulling was quantified by recording the number of clumps of pasture that have been “pulled” from the soil, a method adapted from Houlbrooke (1996). The size of each

clump was established by scoring each clump based on the approximate diameter of the clump. Three size classes were established; small (<10 cm); medium (10-20 cm); or large (>20 cm). The pasture species proportion of each quadrat was also estimated, along with observations of presence of other plant species.

Figure 3.1: An example of the quadrat used when measuring pasture pulling.

3.4 Initial soil characterisation

An initial soil characterisation was conducted in conjunction with the first seasonal sampling, which involved choosing a representative sampling site for each paddock, undertaking a full soil profile description of each seasonal monitoring site, and measuring the pH with depth.

3.4.1 Soil profile description

A full soil profile description was undertaken for each site following Milne (1995). In each paddock a site was chosen as to best represent the paddock, and a pit was excavated by hand using a spade and a shovel, up to the C horizon (approximately 40-50 cm depth). A full soil description was undertaken. Each horizon was described and sampled. Horizon

notation was recorded following Clayden and Hewitt (1994) and then the soil was classified using the New Zealand Soil Classification (Hewitt, 2010).

3.4.2 pH measurement

The pH of each soil horizon was measured for each paddock. A bulk sample was taken from each horizon in the field and taken back to the lab and sieved using a 2 mm sieve and left to air dry for approximately 3 days. The pH was then measured following Blakemore *et al.* (1987). 10 g of air dried soil was placed into a 100 ml beaker and 25 ml of distilled water was added to it. The mixture was stirred vigorously with a high-speed stirrer for 30 seconds and left to stand for 24 hours. The pH was then measured using the Jenway 3510 pH meter, calibrated using standard solutions of pH's 4 and 7.

3.5 Seasonal monitoring programme

A seasonal monitoring programme was established to determine what physical, chemical and biological characteristics varied seasonally in the monitored paddocks. Seasonal monitoring occurred four times throughout the year; summer - 20-24th January; autumn - 7-10th April; winter - 14-17th July; and spring - 6-12th October in 2014. Each monitoring event involved randomly selecting one subplot in each paddock. The current grazing situation, soil moisture, soil dry bulk density, penetration resistance, depth and dry weight of roots, and presence of soil organisms were recorded for each subplot.

3.5.1 Current situation

Notes were recorded on the current situation of each site, such as time since last grazing, previous cropping history, age of pasture, recent weather, if the site had been irrigated, fertiliser usage, cultivation, and any other management practices or observations.

3.5.2 Penetration resistance

A hand-held penetrometer was used to measure the penetration resistance of the soil in each subplot. The penetration resistance was measured by pushing the probe of the hand-held penetrometer into the soil at a constant rate until the probe penetrated the soil to the engraved line on the probe (Figure 3.2). The force required to push the probe into the soil was recorded on the instrument, which measures the resistance and therefore soil strength. Ten reps per depth (0-5, 5-10, 10-20 and 20-30 cm) were measured.

Figure 3.2: The penetration resistance of the soil being measured using a hand-held penetrometer.

3.5.3 Soil moisture content

Soil moisture content was calculated by taking a subsample from each soil dry bulk density core and oven-drying the sample at 105 °C for 24 hours. The moisture content was then calculated using the following equation:

$$Gravimetric\ soil\ moisture\ content\ (\%) = \frac{Mass\ of\ moist\ soil\ (g) - mass\ of\ dry\ soil\ (g)}{mass\ of\ dry\ soil\ (g)}\ x\ 100$$

3.5.4 Soil dry bulk density

Soil dry bulk density was assessed by taking soil cores and measuring the dry mass of the soil relative to the volume, using a method adapted from Blake and Hartge (1986). Three soil dry bulk density cores were collected for depths 0-5, 5-10, 10-20 and 20-30 cm, per subplot during each seasonal sampling. A 5 mm long x 6 mm diameter steel ring was driven into the soil using a wooden mallet, and the sample retrieved from the ground by carefully digging out the core. After the core was removed from the soil (still in the steel ring), the excess soil was trimmed with a knife at both ends so the exact volume could be obtained, and the soil core was then removed and stored in a sealed plastic bag. In the laboratory the samples were weighed before sub-sampling to measure moisture content, which was used to determine the soil dry bulk density of each sample using the following equation:

$$Soil\ dry\ bulk\ density\ (g\ cm^{-3}) = \frac{equivalent\ oven\ dry\ mass\ of\ soil\ (g)}{volume\ of\ soil\ (cm^3)}$$

Equivalent oven dry mass of soil was calculated by dividing the wet weight of the soil core by the moisture factor using the following equation:

$$Equivalent\ OD\ mass\ of\ soil = \frac{wet\ weight\ of\ soil\ core\ (g)}{Moisture\ factor\ \left(\frac{soil\ moisture}{100} + 1\right)}$$

3.5.5 Dry root density

The soil dry bulk density cores were also used to measure dry root density. After the soil samples were weighed to determine soil dry bulk density, the cores were refrigerated until the roots could be extracted. The roots were separated from the soil by wet sieving through a 2 mm sieve, and oven dried at 70 °C for 24 hours. The dry mass was weighed and used to determine the dry root density. Dry root density was calculated using the following equation:

$$Dry\ root\ density\ (mg\ cm^{-3}) = \frac{Dry\ root\ mass\ (g)}{volume\ of\ soil\ (cm^3)}\ x\ 1000$$

3.5.6 Presence of soil organisms

The presence of soil organisms such as black beetle, grass grub, earthworms etc. was recorded by adapting a method from Shepherd (2009), in which a cube (20 cm x 20 cm x 20 cm) of topsoil was extracted. The cube of soil was broken apart carefully by hand and the number of earthworms and other soil organisms were recorded.

3.6 Statistical analysis of results

Statistical analyses were carried out using Microsoft Excel 2013 and GenStat 16th edition.

Chapter 4 - Soil Characteristics and Site Description of Pouakani Dairy Farms

4.1 Introduction

Chapter 4 describes the initial site investigation and characterisation of each soil profile at the study sites, including the site description, paddock history, full soil profile descriptions, and soil pH measured at the start of the investigation.

4.2 Site description

4.2.1 Study area

Pouakani dairy farms, owned by the Wairarapa Moana Incorporation, are located approximately 10 km from Mangakino, a small township in south Waikato, North Island of New Zealand. Mangakino lies on the edge of the Taupo Volcanic Zone (Figure 4.1), which is a zone of volcanic activity that cuts across the central North Island from Mt Ruapehu in the south-west to White Island in the north-east. The landscape surrounding Mangakino ranges from strongly rolling to undulating farmland, and plantation forest. The morphology of the landscape (Figure 4.2) is strongly controlled by the geology and topography of the region, with plateau-forming ignimbrites and gullies carved into the landscape from erosion (Selby & Hosking, 1973). Bluffs and rock outcrops are commonly visible throughout the landscape.

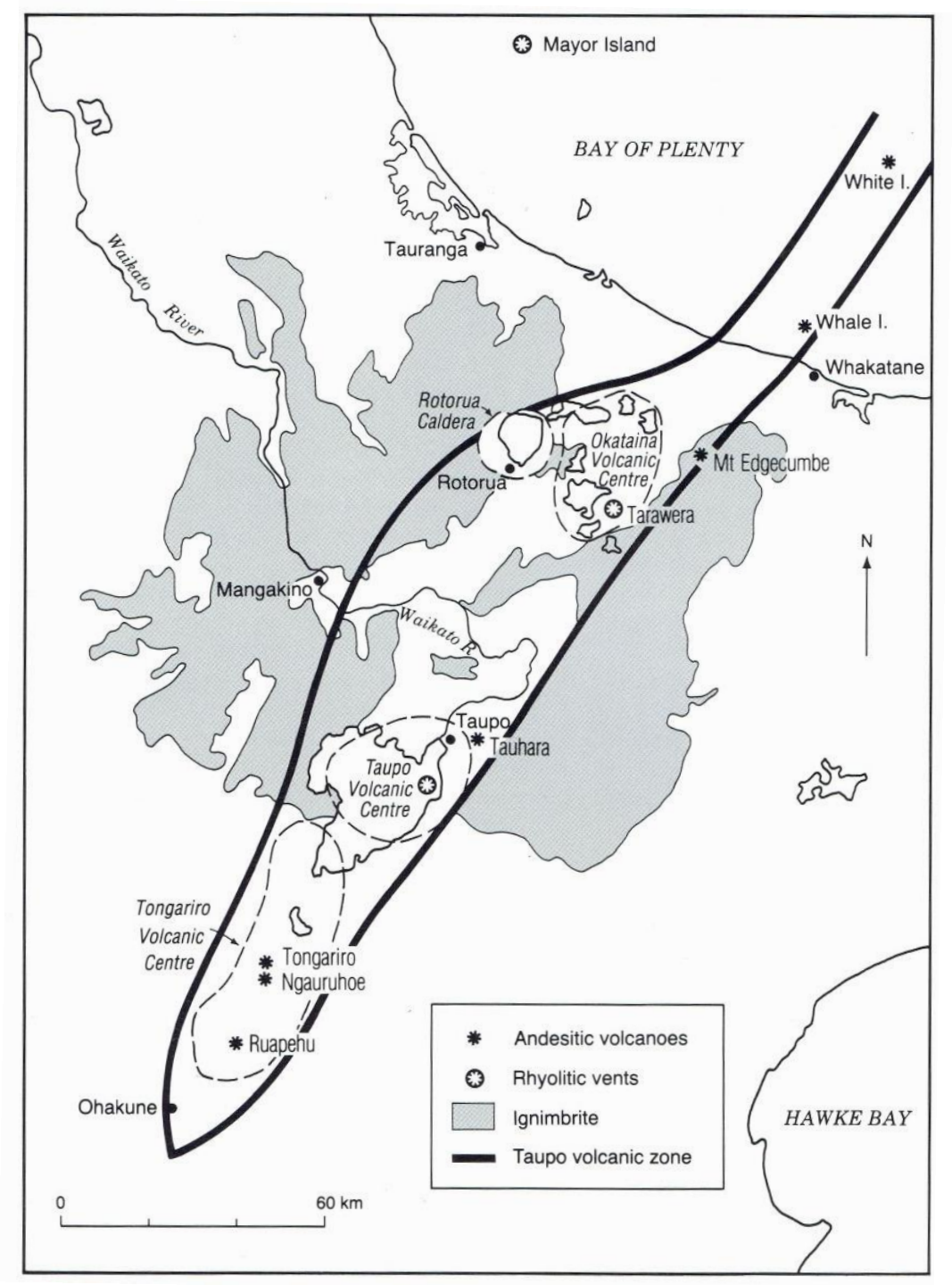


Figure 4.1: The Taupo Volcanic Zone, with Mangakino situated just east of the boundary (Molloy et al, 1998).

The landscape has been repeatedly covered in volcanic material including tephra, lapilli and pumice, from numerous eruptions in the Taupo Volcanic Zone. Soils surrounding Mangakino have been derived from Taupo pumice deposits from the Taupo eruption which occurred in 232 ± 4 AD

(Hogg *et al.*, 2012) which has led to the formation of Pumice Soils in the area.

Figure 4.2: The typical topography in the Mangakino area.

4.2.2 Climate

Mangakino has a temperate climate with a mean annual temperature of 13 °C and a mean annual rainfall of 1403 mm. The area is susceptible to very dry, hot summers and cold winters with many frosts, with sunshine hours averaging 2050 per year. The region is sheltered by high country so has less wind than some other parts of New Zealand. The farms studied were at an altitude of approximately 250 m.

4.2.3 Vegetation and land use

Pouakani dairy farms were predominantly perennial ryegrass pasture. The dairy farms had been operating for approximately 5 years prior to this study. Before this, the land was used primarily for sheep and beef grazing.

4.3 Paddock history

Pouakani dairy farms, have a typical cropping/pasture rotation that they apply to each paddock. The rotation takes approximately two years, after which the paddock is placed in permanent pasture which is expected to last up to eight years. Each paddock is sprayed, and then cultivated using a disc or power harrow. The paddock is then placed into annual ryegrass for approximately 8 months until it is sprayed off again and direct drilled or power harrowed and placed into a winter crop or maize. After approximately 4-6 months, the paddock is then direct drilled with annual ryegrass or left to fallow, for approximately another 6 months. It is then again sprayed, and direct drilled or roller drilled into a summer crop such as chicory or turnips. After another 6 months approximately, the paddock is then sprayed off one last time, and direct drilled with permanent pasture (Figure 4.3).

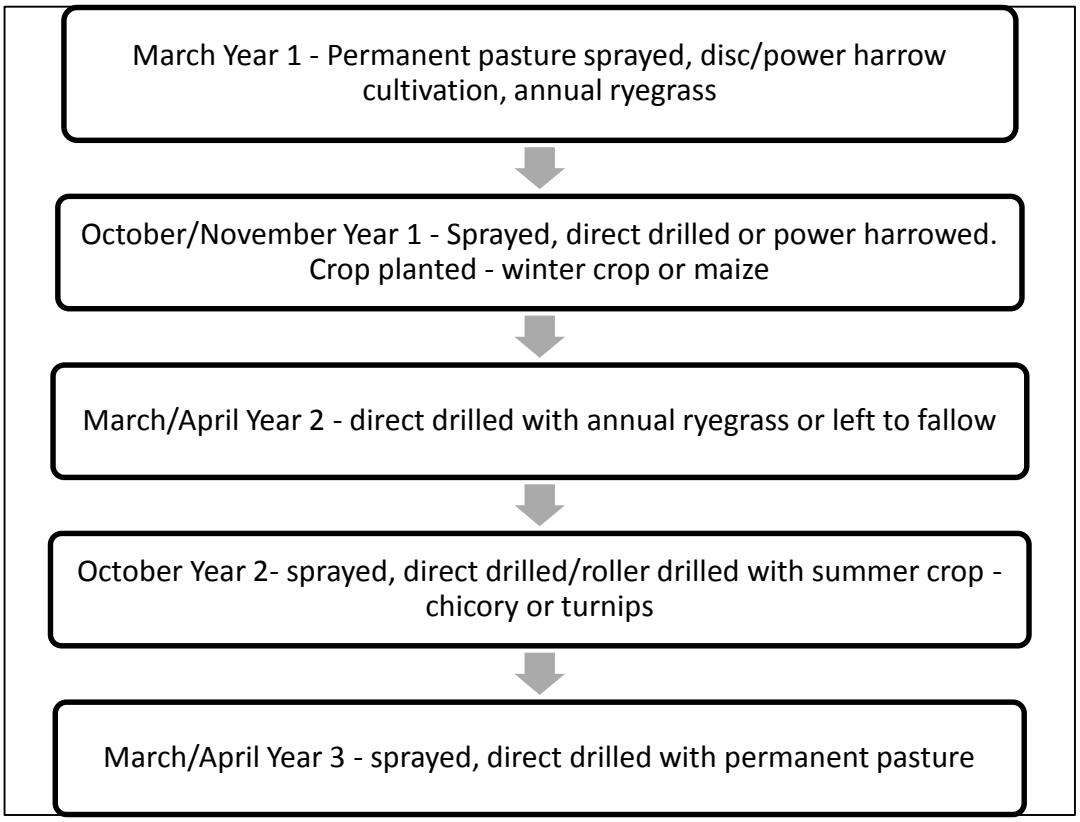


Figure 4.3: Diagram illustrating the cropping and pasture rotation that is applied at Pouakani dairy farm.

The fifteen paddocks investigated in my study were selected based on having undergone similar management practices, so they could be compared. The paddocks were all treated to the same fertiliser regime. The principal difference between paddocks was the pasture age, as it was hypothesised that pasture age was a factor in the susceptibility to pasture pulling. Table 4.1 lists the history of each paddock in the study.

Table 4.1: Management history and time in pasture for each paddock in the study (D. March, personal communication, 2014).

Farm	Paddock	Pasture sown	Direct Drilled or broadcast	Cultivated	Time in pasture (years)	Crops before pasture
15	8	Apr-13	Direct Drilled	Cultivated	1	Swedes Nov 2011 - Chicory Oct 2012
14	147	Apr-13	Direct Drilled	Cultivated during crop	1	Swedes Nov 2011 - Chicory Oct 2012
9	31B	Apr-13	Broadcast	Cultivated	1.5	Turnips - 6 months
9	32A	Apr-13	Broadcast	Cultivated	1.5	Turnips - 6 months
11	A16	Apr-12	Direct Drilled	Cultivated during crop	2	Moata - Chicory
15	35	Apr-12	Direct Drilled	Cultivated	2	Swedes Nov 2010 - Chicory Oct 2011
14	146	Apr-11	Direct Drilled	Cultivated during crop	3	Swedes Nov 2010 - Chicory Oct 2011
15	37	Apr-11	Direct Drilled	Cultivated	3	Swedes Nov 2009 - Chicory Oct 2011
15	15	Apr-11	Direct Drilled	Cultivated	3	Swedes Nov 2008 - Chicory Oct 2010
14	148	May-11	Direct Drilled	Cultivated during crop	3	Swedes Nov 2010 - Chicory Oct 2011
15	17	Apr-11	Direct Drilled	Cultivated	3	Swedes Nov 2008 - Chicory Oct 2010
14	125	Apr-10	Direct Drilled	Cultivated during crop	4	Swedes Nov 2008 - Chicory Oct 2009
14	149	5+ years	Broadcast	Cultivated	5+	N/A
11	B12	5+ years	Broadcast	Cultivated	5+	N/A
9	33	5 + years	Broadcast	Cultivated	5+	N/A

The management practices for each paddock were similar, with most paddocks containing direct drilled pasture and only 5 broadcast sown. Paddock 149 from Farm 14 was sown with a pasture which, at the

beginning of the trial (January 2014), was 5+ years old, and was predominantly browntop pasture. In June 2014, the paddock was cultivated, and has been re-sown with annual ryegrass. Paddock 17 from Farm 15 contained pasture at least 3 years old, but in April 2014 it was sprayed and direct drilled with new pasture.

4.4 Soil profile descriptions

As part of the initial site description, full soil profile descriptions were taken in each paddock to the C horizon, (Appendix 1). There were two main Pumice Soil types identified, a Typic Orthic Pumice Soil, and an Immature Orthic Pumice Soil (Figure 4.4). Both soils were similar, but had enough variation in the B horizon to distinguish between the different soils. Immature Orthic Pumice soils are soils which contain a Bw horizon that is 30 cm or less thick, and has hue 10 YR or yellower and chroma 4 or less. Soils which did not fit the colour requirement were classed as Typic Orthic Pumice soils.

The soils were similar as they were all sandy loams, but had slight variations in the depths of each horizon, notably the Ap horizon which was on average 13 cm in depth but in some paddocks was up to 22 cm in depth. The B horizon for most paddocks was not prominent, and transitioned into the C horizon at shallow depths. The C horizon texture varied between paddocks, with some paddocks containing coarse pumice, and some only fine sands and lithics. In some paddocks a dark organic horizon was identified just below the Ap horizon, and appeared to be evidence of burning from previous clearing of the land prior to sheep and beef grazing.

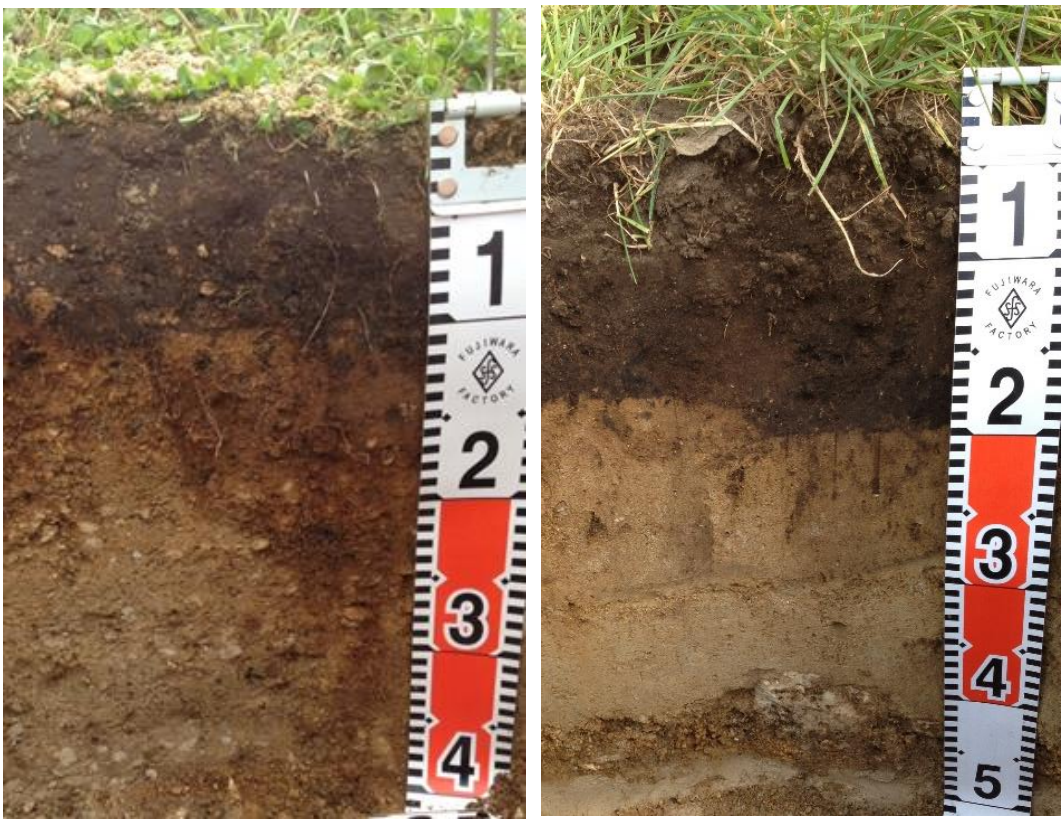


Figure 4.4: Typical soil profiles of a Typic Orthic Pumice Soil (left) and an Immature Orthic Pumice Soil (right).

Pumice fragments were present in each paddock, but varied in the amount and size of the clasts. It appeared that the pumice was coarser in areas of lower elevation. Coarse pumice pieces were present in the Ap horizon of some paddocks, which could have been due to being transported from another horizon when the soil was cultivated.

In most paddocks a platiness of the soil occurred in the Ap horizon at approximately the 5-10 cm depth (Figure 4.5). Root observations showed that the majority of the root biomass was in the top 5 cm. The roots often penetrated into the soil to 5 cm depth and then began to grow horizontally at the top of the zone where the soil breaks off in a plate-like manner. Roots were seen to penetrate lower than the 5 cm depth but were fewer than in the top 5 cm of the soil.

Figure 4.5: A photograph of the soil in paddock 8 which exhibits platy soil structure in the 0-10 cm depth.

4.5 Soil pH

The pH of the soil was measured in the paddocks studied (Appendix 2). Each soil horizon was measured, and the Ap horizon was further divided into 0-5 and 5-10 cm depths to determine if there was a change in pH with depth. The pH of all depths in each paddock ranged between 5.2 and 6.5, with a mean pH of 5.7 (slightly acidic). The pH is generally within the recommended pH range for ryegrass, which is 5.5 to 6.5 (McLaren & Cameron, 1996). There were no statistically significant changes in pH between paddocks, or between horizons within the same paddock.

4.6 Summary

The soils in the study comprised Typic Orthic Pumice Soil, and Immature Orthic Pumice Soil. The soils were similar in all properties, with all soils exhibiting a dominant sandy loam texture with varying pumice clast contents. The pH values measured ranged between 5.2 and 6.5 but no significant differences in pH were seen with depth or between paddocks.

Chapter 5 - Results of the Pasture Pulling Assessment

5.1 Introduction

This chapter contains the results of the pasture pulling assessment from January - December 2014. The mean pasture pulling data are presented, and a pasture pulling index is also introduced which was used to account for the size of the pulls, and therefore, the severity of pasture damage caused by the pulling. The changes in pasture species composition over the year are also included, along with a discussion. Full data sets are included in Appendix 3. All pasture pulling data were square root transformed as part of the statistical analysis to stabilise the variance of the residuals.

5.2 Pasture pulling mean per quadrat

Pasture pulling occurred throughout the year, and was most severe during the late summer/autumn period and least severe during the winter (Figure 5.1). In spring pasture pulling numbers began to increase, and continued to increase in December (start of summer). There was a lot of variability in the number of pasture clumps pulled per quadrat. Over the whole year, across all paddocks, a mean of 2.8 pasture clumps per quadrat were pulled, with some quadrats recording up to 30 clumps of pasture pulled, and some quadrats not recording any pulls (Appendix 3). There was some pasture pulling, at some stage of the year, in every paddock that was assessed.

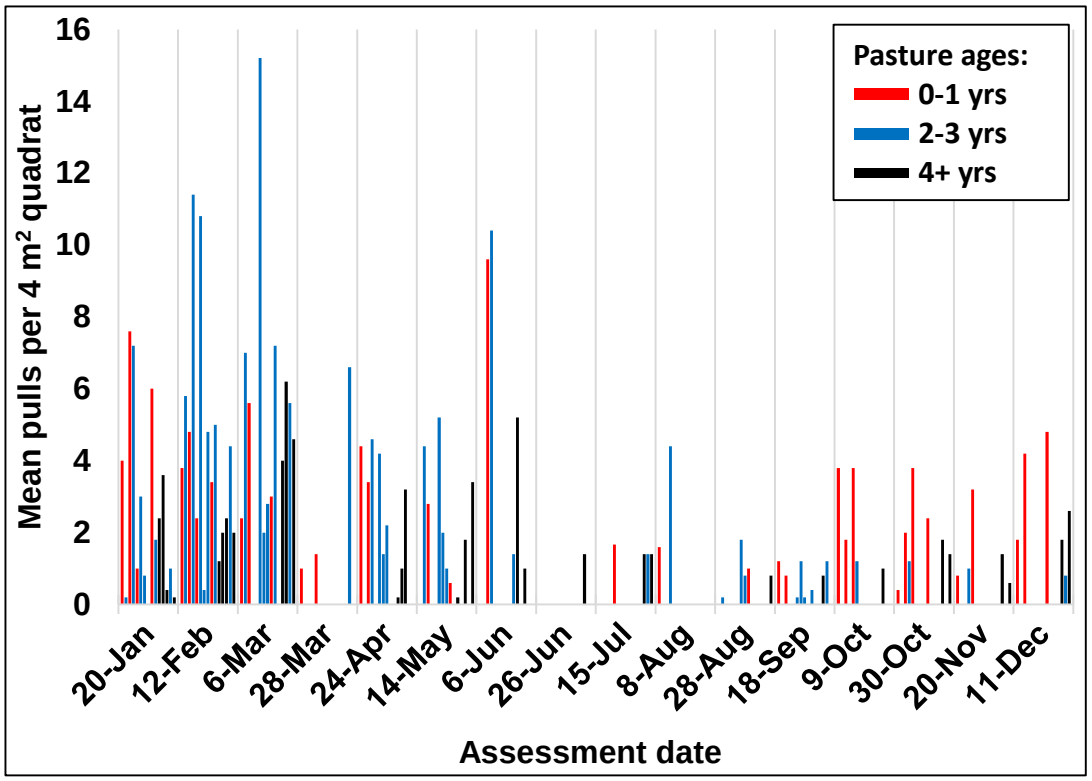


Figure 5.1: The mean number of pulls per quadrat in each paddock for the year, colour coded by pasture age group.

The grazing rotation changed throughout the year (Table 5.1), with much less grazing undertaken in winter. Pasture pulling assessments were only conducted on paddocks that had been grazed since the previous pasture pulling assessment, so there are gaps in Figure 5.1 where paddocks had not been grazed since the previous assessment. A lot of pulling was recorded in summer/early autumn, when the paddocks were regularly grazed.

Table 5.1: The approximate grazing rotation for each month at Pouakani dairy farms (Data supplied by D. March).

Month	Rotation Length/Grazing Interval (approx.)
Oct, Nov, Dec, Jan, Feb	20 days
Mar	30 days
Sep, Apr, May	40 days
Jun, Jul	80 days
Aug	60 days

Each paddock had some pulling at some stage of the year (Figure 5.2). Some paddocks such as 15, 147 and A16 had more pulls than others. Paddocks such as 31B pulled at a steady rate throughout the year, with less than 10 pulls per quadrat, and others such as paddock 35 pulled in the autumn but not later in the year.

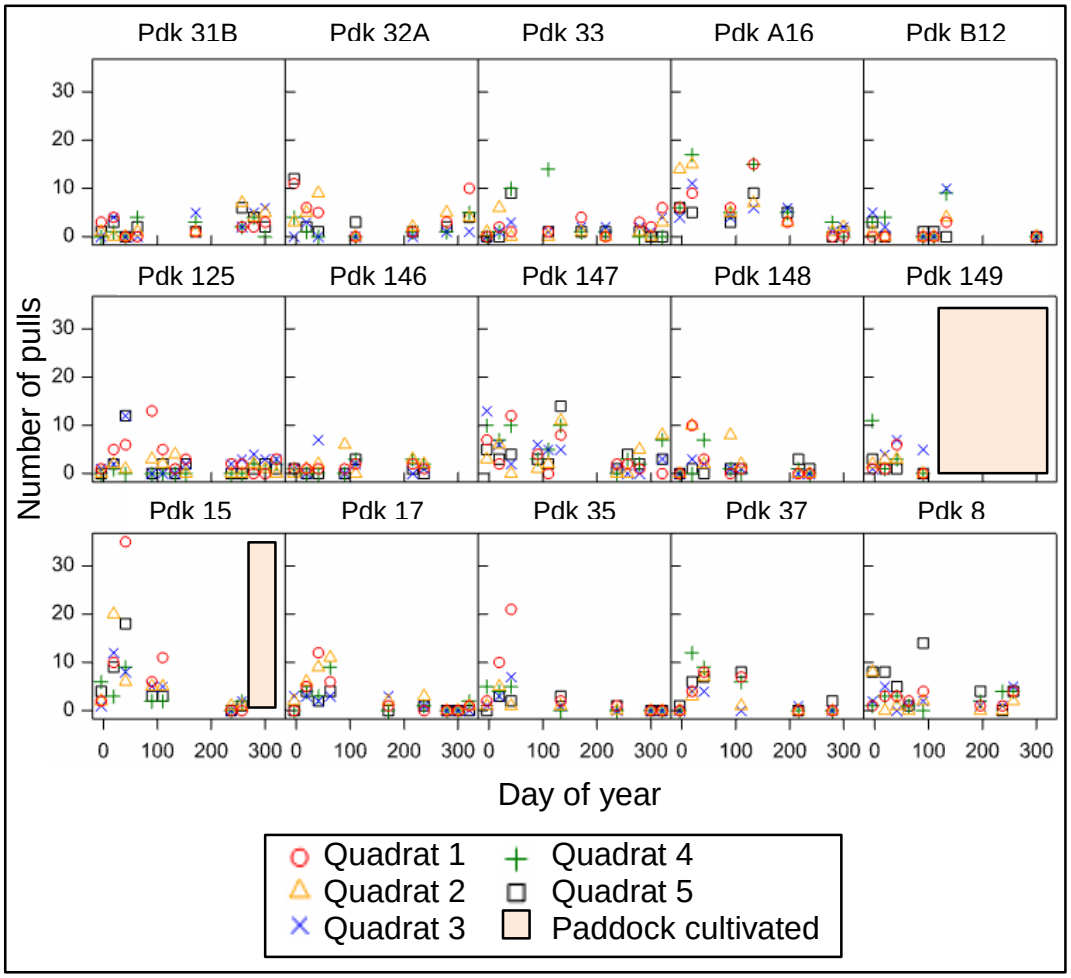


Figure 5.2: The number of pulls per quadrat for each assessment, for every paddock studied.

5.3 Pasture pulling clump size variations

Small pulls (<10 cm) were the dominant size range to pull (Figure 5.3). The shape of the pulls (Figure 5.4) was predominantly clumps of pasture, where pasture had grown in clumps and was dislodged from the soil by grazing stock. On occasions a more “mat-like” pull was seen, which was generally in the medium-large size class.

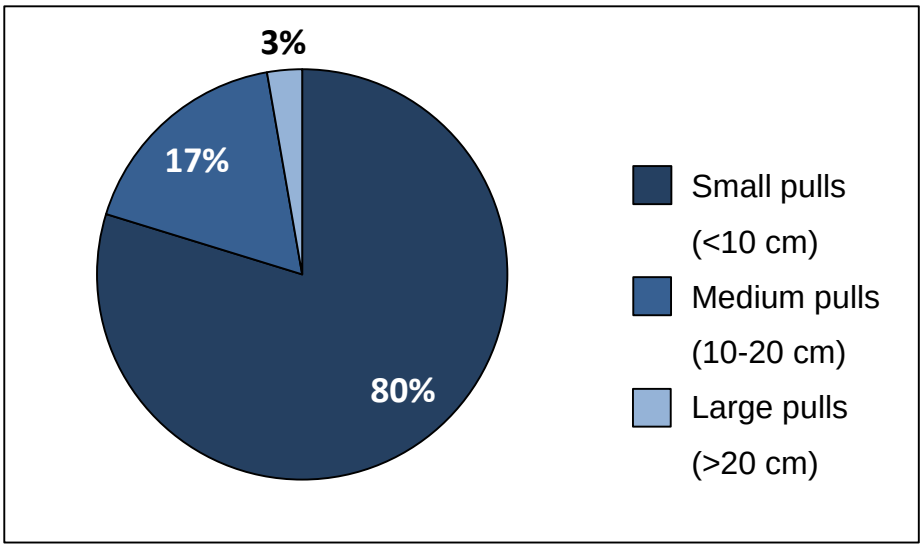


Figure 5.3: The size distribution of pulled clumps recorded over the year.

Figure 5.4: Different types of pulling were observed, such as clumps of pasture pulled on the left, and "mat-like" pulls on the right.

Small pulls were generally the most common size of pull throughout the year (Figure 5.5), peaking in summer, with medium pulls not as prominent in summer. However, in winter medium (10-20 cm) sized pulls occurred more often, and were the most common size for the pasture pulling assessment conducted on the 8th August. Medium pulls were uncommon in spring. Large (>20 cm) pulls were uncommon throughout the trial, only present in a few cases.

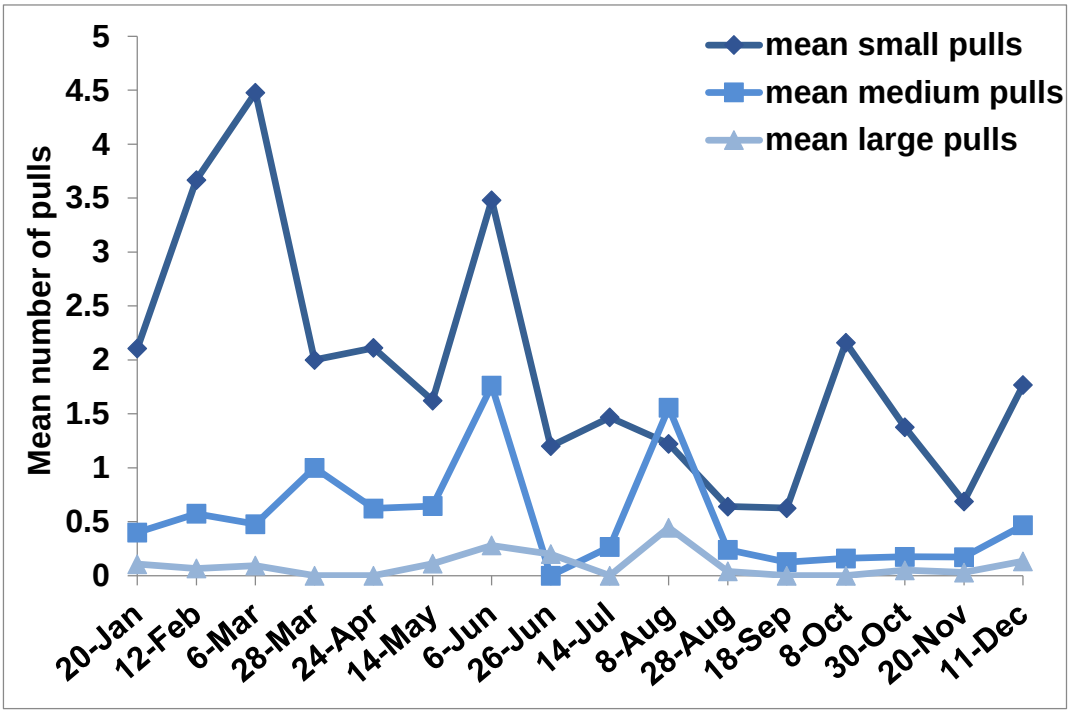


Figure 5.5: The mean number of small, medium and large pulls per quadrat, for each pasture assessment across all paddocks studied.

5.4 Pasture pulling index

The results of the pasture pulling assessment (Section 5.2) were presented as an average of all pulls per quadrat, for each pasture age group, for every assessment (Figure 5.1). The mean pulls per quadrat did not take into account the size of the pulls, which were important because the size of the pasture clump that was pulled determined the severity of the damage to the pasture. To account for the size of the pulls, a pulling index was created. The pulling index was calculated using an equation which multiplied the medium (10-20 cm) and large (<20 cm) sized pulls by

a number to account for the increase in the size of the clump. The following equation was developed:

$$Pasture\ pulling\ index = mean\ number\ of small\ pulls + (mean\ number\ of\ medium\ pulls\ x\ 3) + (mean\ number\ of\ large\ pulls\ x\ 5)$$

Weighting the pasture pulling data by using the pasture pulling index (Figure 5.6) showed the same overall trend as the total pulls.

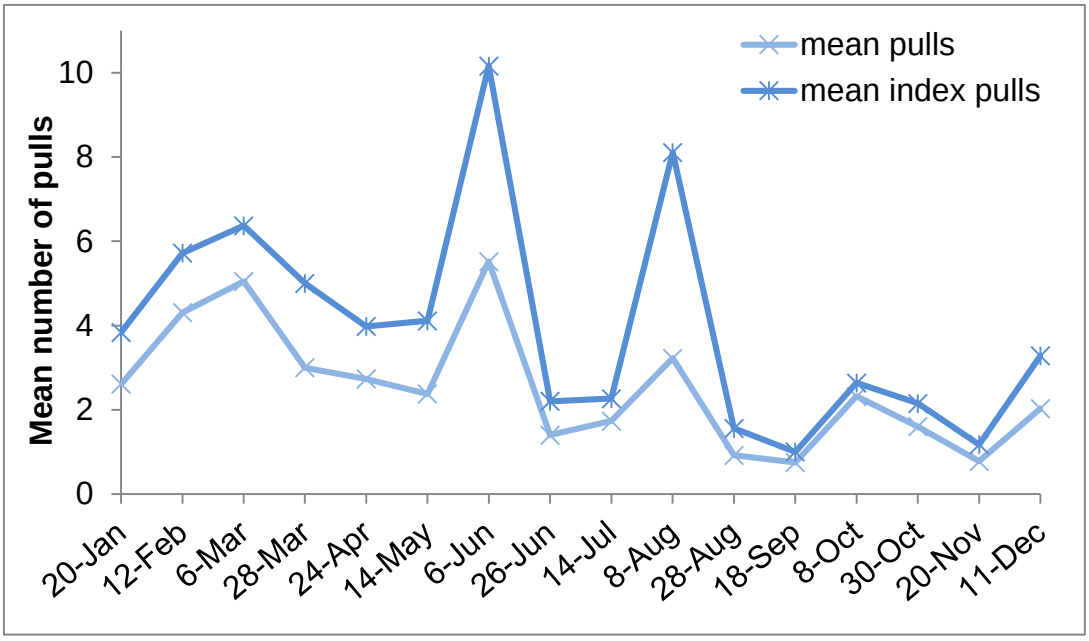


Figure 5.6: The mean pulls, and pasture pulling index weighted mean pulls per quadrant for each pasture pulling assessment.

However, the pulling index showed an increase in the severity of pulling compared to total pulls. Where the pulling index is greater than total pulls, the pulling index shows the pulling damage to be worse because it reflects the larger number of bigger clumps being pulled. This is particularly evident in the difference between total pulls and the pulling index from pasture pulling assessments conducted on the 6th June, and 29th August.

5.5 Statistical analysis of pasture pulling

Statistical analyses were conducted using GenStat to examine if there were significant relationships in the data. The paddocks were grouped based on their pasture ages (1 year old pastures, 2-3 year old pastures, and 4+ year old pastures). The mean number of pasture clumps pulled per quadrat for each group is presented, using a REML (restricted maximum likelihood, a method for fitting linear mixed models) analysis (Figure 5.7). The data were square root transformed to stabilise the variance in the residuals.

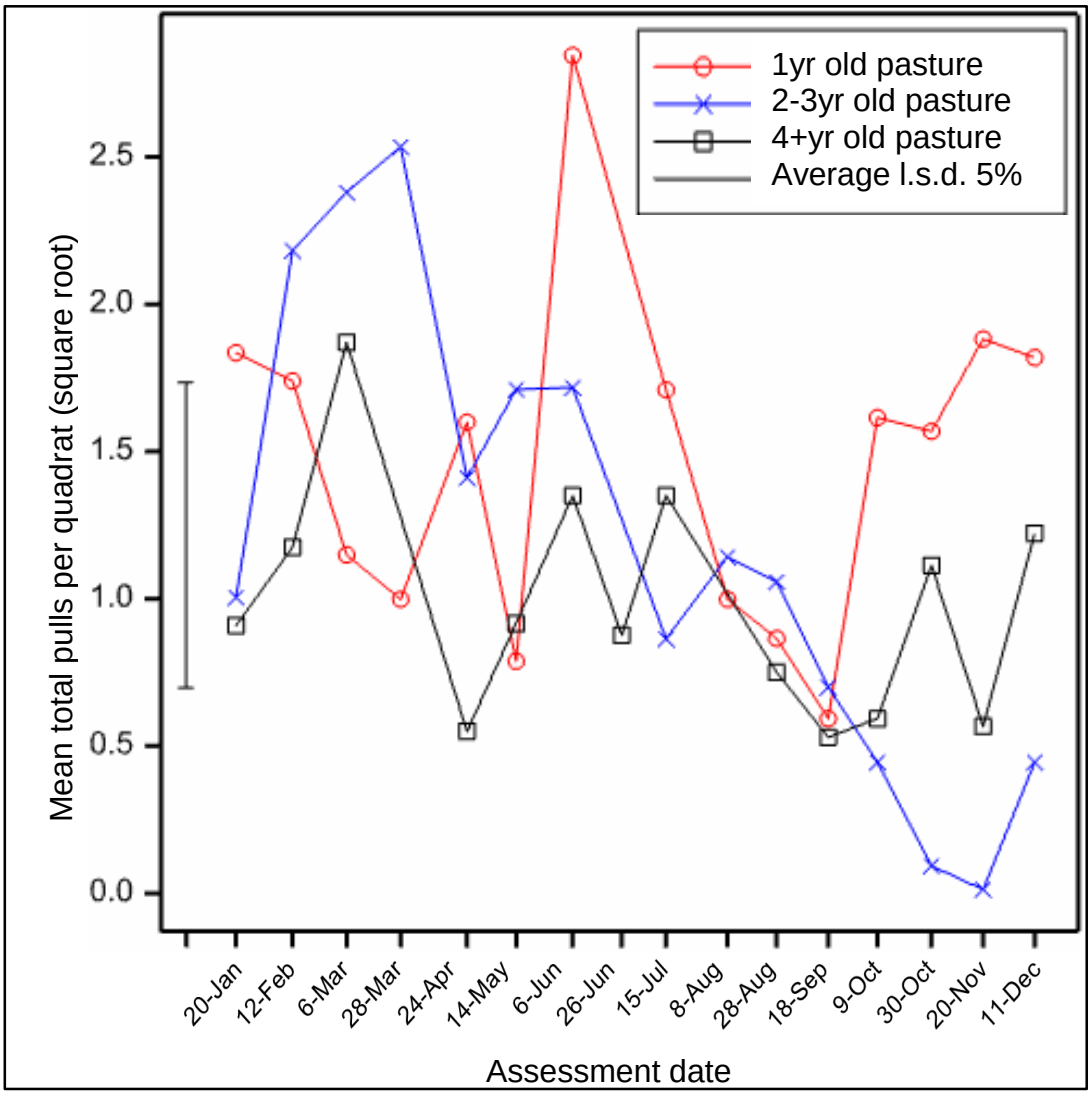


Figure 5.7: The mean square root number of total pasture clumps pulled per quadrat from each assessment, from the 3 different age groups.

For the number of pasture pulls per quadrat there was an interaction between pasture age group and the date of assessment (P<0.001, Table 5.2). That is, the trend through time depends on the pasture age group.

Table 5.2: P-values for the interaction between total pulls, total pulls with pasture pulling index, and for each size range with assessment date and pasture age.

Sequential Term	Total pulls	Pulling index	Small pulls	Medium pulls	Large pulls
Assessment date	<0.001	<.0.001	<0.001	<0.001	0.014
Pasture age group	0.361	0.318	0.532	0.141	0.683
Pasture age group x assessment date	<0.001	<.0.001	<0.001	<0.001	0.679

The 1 year old pastures had the most variable trend; pulled at high rates during summer, and the one assessment carried out in winter showed pulling to be at its worst then. The pulling in the 1 year old pasture decreased from July-September, and then in spring/summer pulling rates increased again. The 2-3 year old pastures pulled most severely during late summer-autumn, and then declined throughout the rest of the year. The 4+ year old pastures pulled worst during the summer and then pulled at a steady rate throughout the rest of the year. The paddocks were also grouped by farm, and a REML analysis was undertaken, but showed no significant relationship between the mean number of pasture clumps pulled per quadrat, and farm.

5.6 Statistical analysis of pasture pulling clump size

There was a significant relationship (P<0.05) between the number of small, medium, and large sized pulls, and assessment date (Table 5.2). There was no significant difference between pasture age group with pull size range (Figure 5.8, Figure 5.9 & Figure 5.10). However, there was a significant interaction (P<0.001) between pasture age group and assessment date for the small and medium sized pulls when considered

separately. Therefore, there are different trends through time for small and medium pulls for different pasture age groups. For large pulls, the interaction between pasture age group and assessment date was not significant.

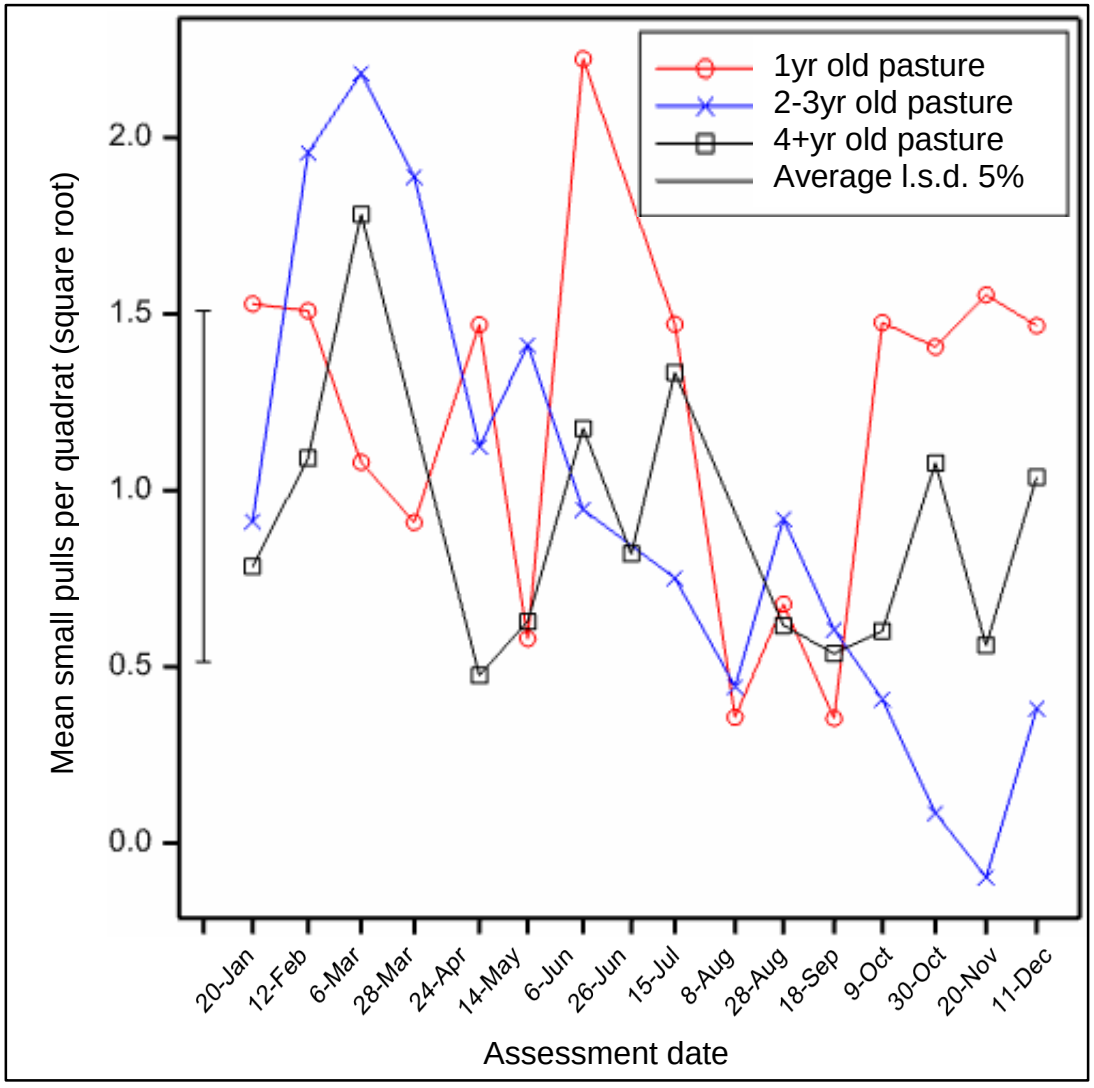


Figure 5.8: The mean square root number of small clumps pulled per quadrat, for each pasture age group.

There was a lot of variation in the number of small clumps pulled throughout the year for all pasture age groups. There were more medium and large pulls in the 1 and 2-3 year old pastures compared to pasture ages of 4+ years (Figure 5.9 & Figure 5.10).

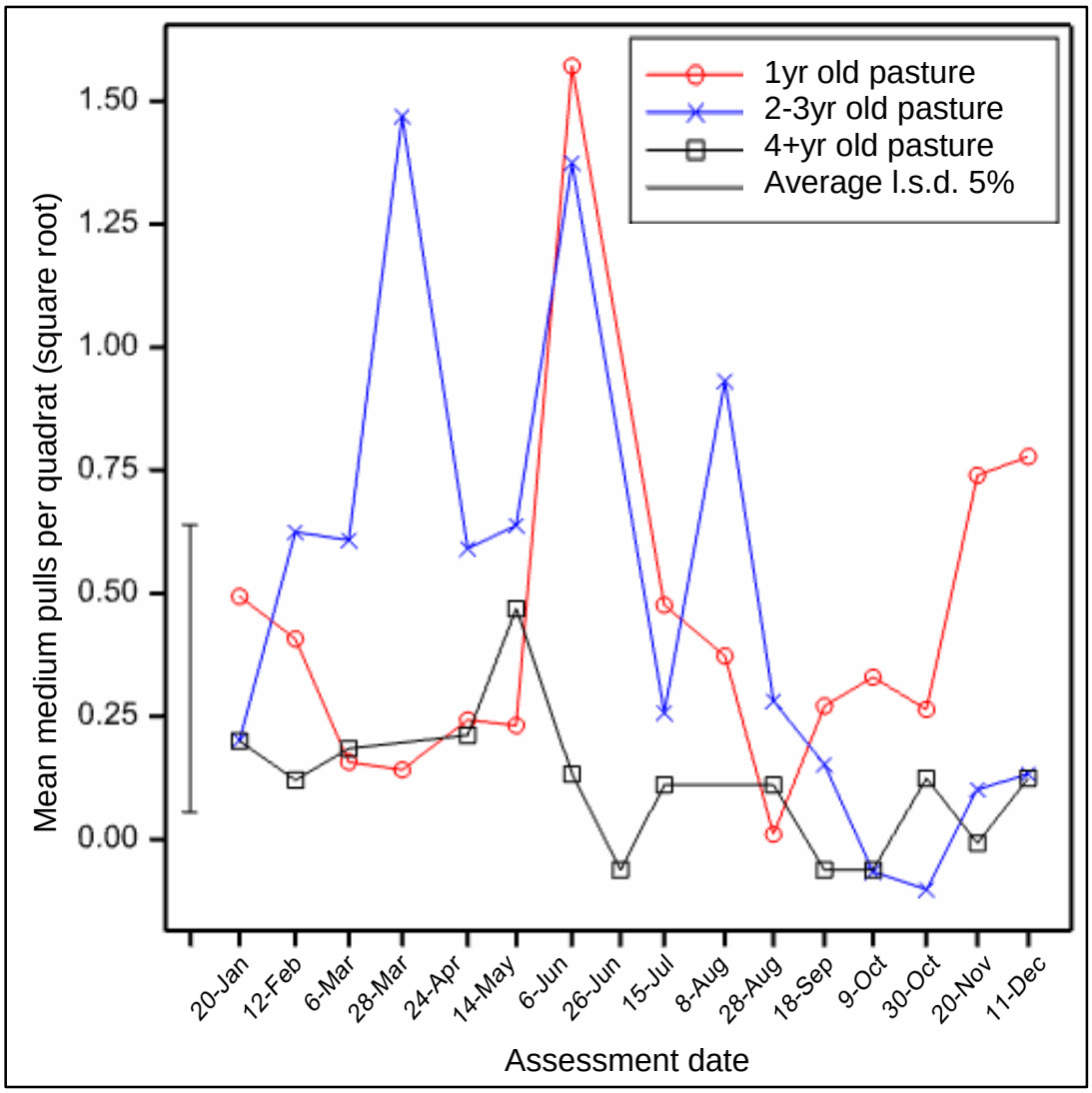


Figure 5.9: The mean square root number of medium clumps pulled per quadrat, for each pasture age group.

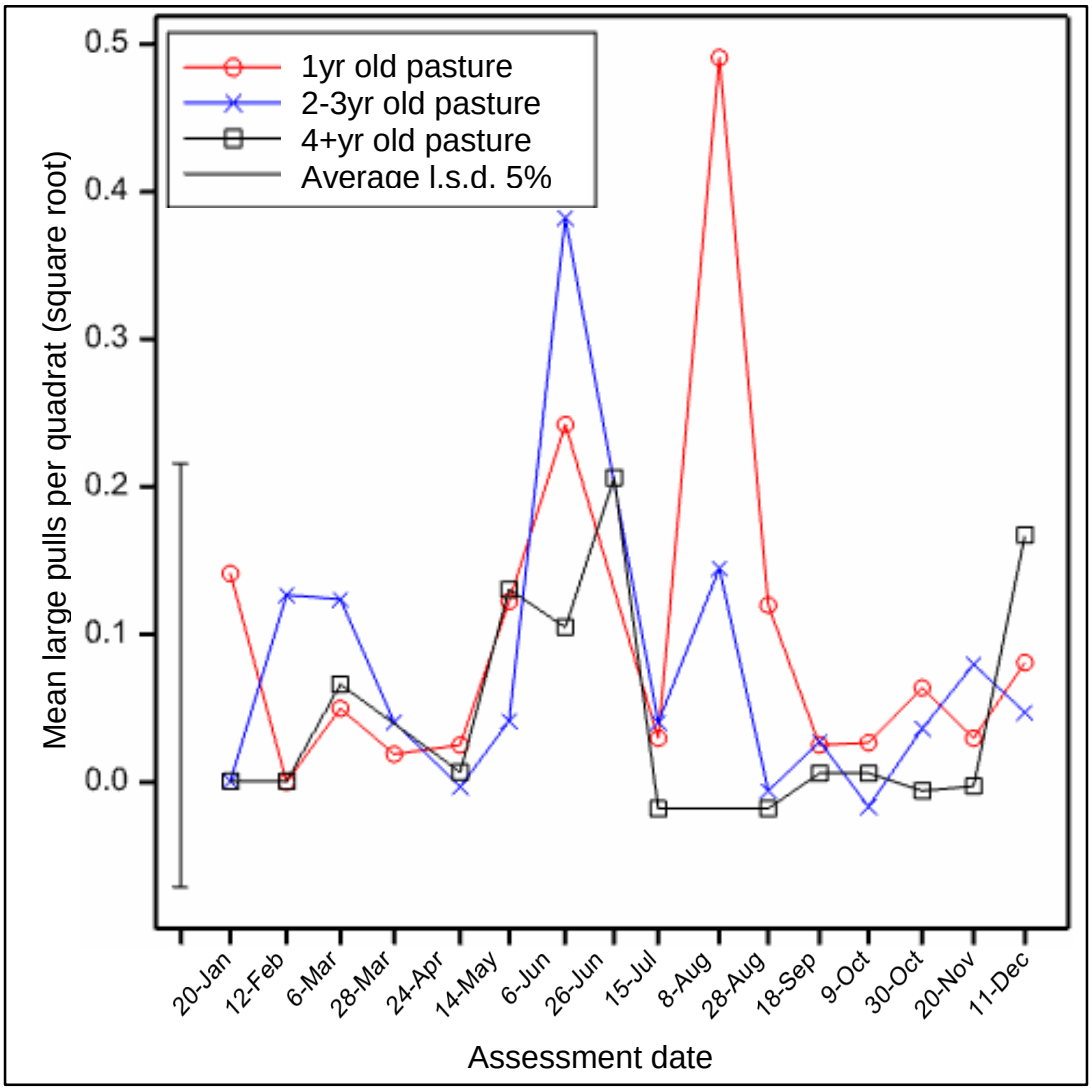


Figure 5.10: The mean square root number of large clumps per quadrat for each pastures age group.

5.7 Statistical analysis of pasture pulling index

The paddocks were grouped by pasture age and a REML analysis was conducted to see if there was an interaction between pasture age and assessment date, when the pulling data were weighted in the pulling index (Figure 5.11). Similar patterns were observed when weighting the data in the pulling index, with the relationship between pulling index and assessment date significant (P<0.001) (Table 5.2). The P-value of the analysis between pulling index and pasture age group was slightly reduced when comparing it to that for the mean total pulls, but was still not significant. For the pulling index the overall interaction between pasture age group and assessment date was significant (P<0.001).

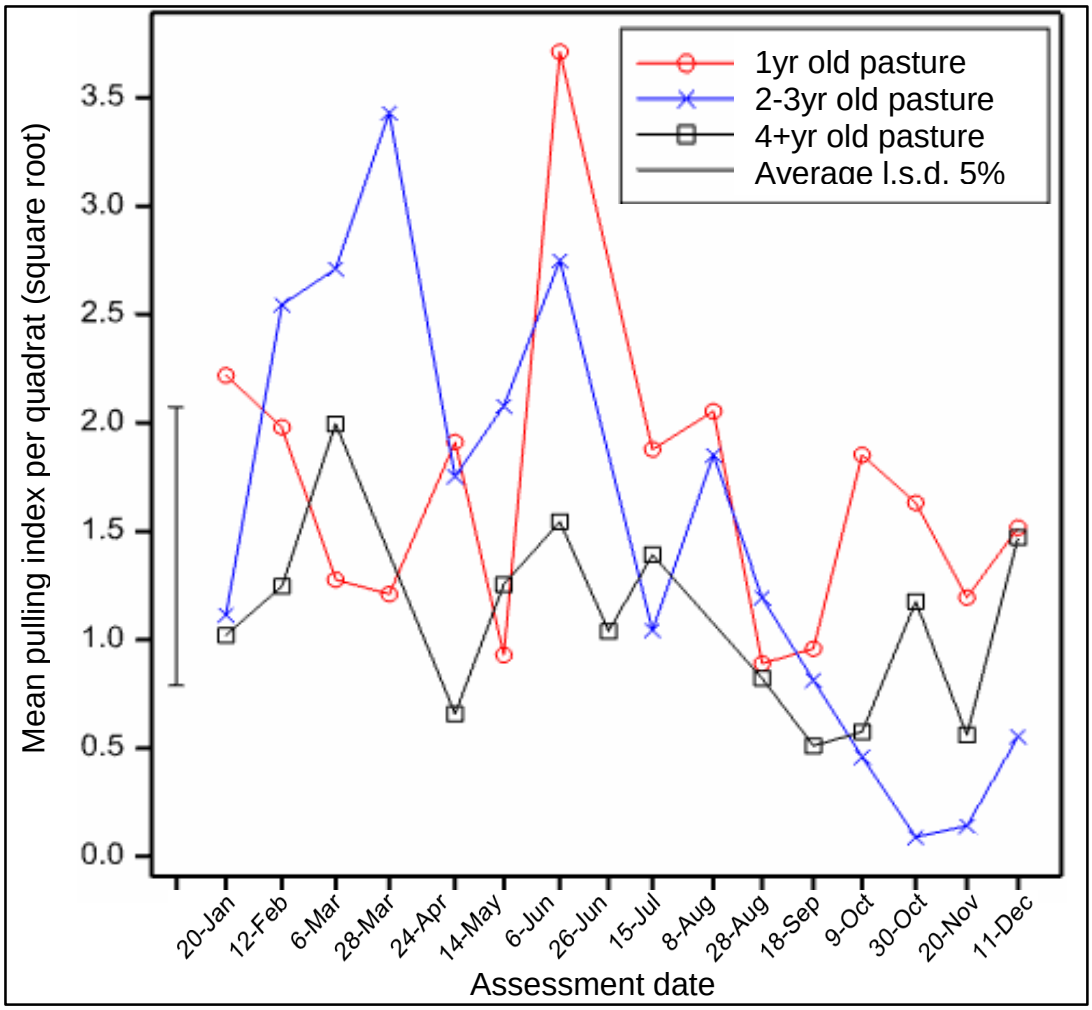


Figure 5.11: The pulling index, weighted mean square root number of pulls per quadrat for each assessment, for each pasture age group.

5.8 Pasture species composition seasonal changes

The dominant pasture species was noted in each quadrat during pasture pulling assessments. The dominant pasture species overall was perennial ryegrass, with browntop, clover and weeds also prominent (Figure 5.12). Patches of bare ground were also common, with other species such as chicory and prairie grass a minor contribution to the sward.

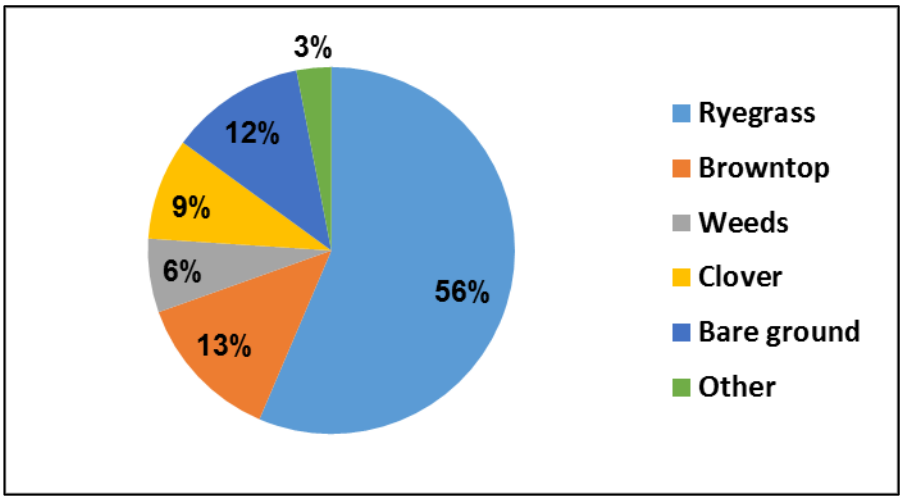


Figure 5.12: The grand mean proportion of pasture type and bare ground per quadrat, for all paddocks throughout the year.

When the paddocks were grouped by pasture age and the dominant pasture species compared, there were differences both between pasture ages and with season. The dominant pasture species in 1 year old pastures was ryegrass, with a large proportion of bare ground and clover (Figure 5.13). The proportion of ryegrass increased throughout the year, with bare ground and clover declining, and was most prominent in spring in the 1 year old pasture.

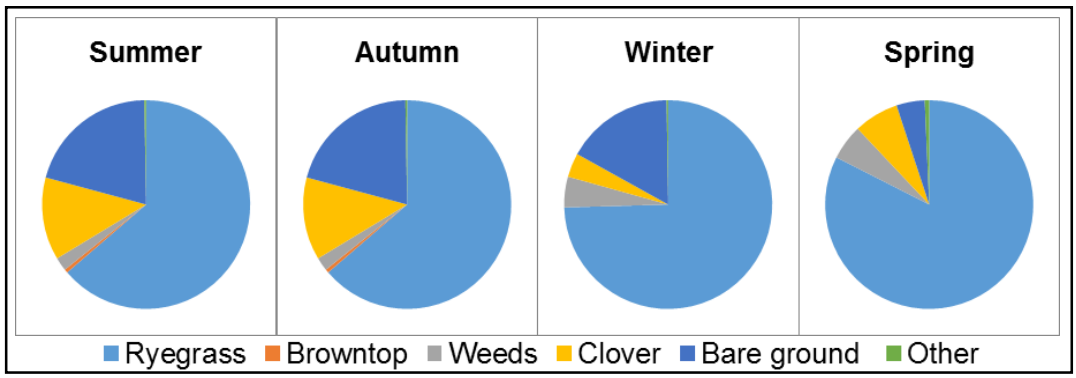


Figure 5.13: The mean proportion of each different pasture species and bare ground in a quadrat, for 1 year old pasture, for each season.

In the 2-3 year old pastures. The dominant pasture species was again ryegrass, but there was a higher proportion of browntop and weeds compared with the 1 year old pasture (Figure 5.14). The proportion of ryegrass increased, and the proportion of other species and bare ground decreased throughout the year.

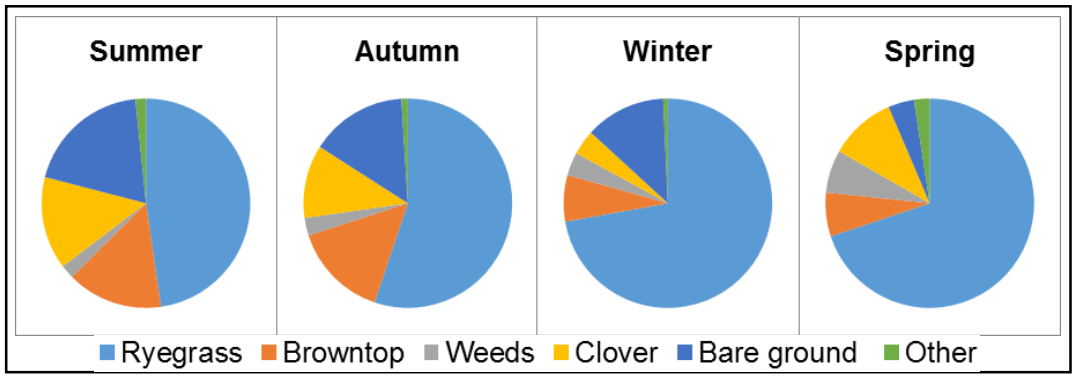


Figure 5.14: The mean proportion of each different pasture species and bare ground in a quadrat, for 2-3 year old pasture, for each season.

In the 4+ year old pastures, there was a much more diverse sward (Figure 5.15). There was more browntop and less ryegrass present, when compared to the other pasture age groups. There was also a higher proportion of weeds than in the other pasture age groups.

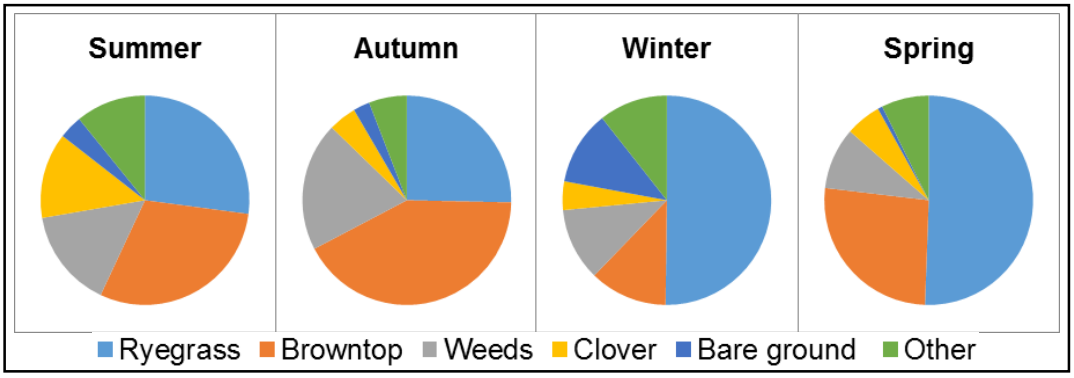


Figure 5.15: The mean proportion of each different pasture species and bare ground in a quadrat, for 4+ year old paddocks, for each season.

In some of the newer pasture paddocks, such as one year old pastures in paddocks 8 (farm 15) and A16 (farm 11), there was a small amount (5-10 %) of chicory still present in the paddocks which remained from the

previous crop. All pulled clumps of pasture were examined when the pasture assessments were undertaken, and all were grass (no pulling was seen of clover, weeds or chicory).

Some of the paddocks had a denser sward of pasture than others. Paddocks which contained younger pastures were quite patchy, with some quadrats comprising of up to 50 % bare ground (Appendix 3). Observations made in the paddocks with younger pastures showed the pasture to be growing in small clumps which were easily pulled during grazing. Paddocks such as A16 and 8 suffered from patches of pasture with a lot of bare ground, and pasture growing in clumps, which were readily pulled from the soil.

5.9 Discussion

Pasture pulling occurred throughout the year, with all paddocks exhibiting some pulling. Pasture pulling was more severe during the late summer and autumn period, and began to increase again as temperatures warmed up in late November/December. Tallowin (1985), Blank and Olson (1988) and Houlbrooke (1996) all also observed pasture pulling to be most common during the late summer and autumn.

Although there was no significant difference between pasture pulling and pasture age group, there was a significant interaction between pasture age group and assessment date. Therefore, there were trends shown that the patterns of pulling in each pasture age group were different. Medium and large size clumps of pasture pulled more in younger pastures. The most common size of pasture pulls were small (0-10 cm), which comprised of 80 % of the pulling total over the year.

There were no significant differences in the number of pulls when the paddocks were grouped by farm. Although each farm applies roughly the same management practices to paddocks, there would be a bit of

variability, so it is inferred that management of paddocks is not related to pasture pulling.

Although pasture pulling was recorded to be lower over the winter, only a small number of pasture pulling assessments were completed due to decreased grazing in winter. The lack of grazing in winter meant there was less opportunity for pasture pulling to occur. In spring, there were a few occasions where paddocks were not assessed for pulling because they had been cut for silage/hay rather than grazed.

On some occasions high pulling events were recorded in particular paddocks, which may have also been due to a number of factors which were unable to be measured, such as differences in the stocking rate, the size of stock grazed (bulls/cows vs calves), and length of grazing.

The pulling index used to weight the pasture pulling data to better describe the effect the size of the pulls had on the severity of the pulling was useful, illustrating the pulling to be more damaging during the late summer and autumn period. Visual observations made in the field saw the pulling to be worse during the late summer and autumn, and the pasture pulling index illustrated this better than just the mean total pulls.

The proportion of ryegrass increased throughout the year, with the highest proportion recorded in spring for all pasture age groups. However, ryegrass proportion was observed to decrease overall as pasture age increased. As pasture age increased, the proportion of ryegrass decreased, and the diversity of the pasture increased, with a higher amount of browntop, weeds, and other species present in the paddocks which contained pasture ages of 4 or more years. The higher diversity in the older pastures could be explained by the paddock having more time for browntop and other species to establish, especially in patches of bare ground.

5.10 Summary and conclusions

- Pasture pulling was observed for one calendar year, in 15 paddocks of different pasture ages on Pouakani dairy farms in the central North Island of New Zealand. Pasture pulling assessments were conducted every 3 weeks if the pasture had been grazed since the last assessment, and involved measuring the amount and size of pasture pulls dislodged from the soil in 5 x 4m^2 quadrats per paddock. Observations were also made of the dominant pasture species in each quadrat, as well as the species of the pulled material.

- Pasture pulling was observed to occur throughout the year, but it was most prominent during the late summer and autumn period. All paddocks pulled at some stage of the year. The pasture pulling index was more effective at illustrating the seasonal trends associated with pasture pulling than the mean total pulls per quadrat.

- There was a lot of variability in the number of pasture clumps pulled per quadrat, with an overall mean of 2.8 pasture clumps per quadrat pulled. Some quadrats recorded up to 30 clumps of pasture pulled, with some quadrats not recording any pulls on a particular assessment.

- There were no significant differences in the number of pulled clumps and pasture age. Small (<10 cm) clumps were the dominant size to be pulled throughout all paddocks (80 % of pulls throughout the year). More medium (10-20 cm) and large (>20 cm) clumps were pulled in the younger (1-3 year old) pastures than in the more established, 4+ year old pastures.

- The dominant pasture species observed across all paddocks was perennial ryegrass. The paddocks with older, more established

pastures contained a higher proportion of other grass species and weeds.

- Only grass was pulled from the soil, other species such as clover, chicory and weeds were not pulled by grazing stock.

Chapter 6 - Seasonal Sampling Results

6.1 Introduction

This chapter presents the results of the seasonal soil sampling in the monitored paddocks, at 4 different depths (0-5, 5-10, 10-20, 20-30 cm). This includes dry root density, penetration resistance, soil dry bulk density, soil moisture content, and presence of soil macrofauna, to establish if there was a relationship between soil properties and pasture pulling. A detailed record of the data from each section can be found in Appendices 4, 5, and 6.

6.2 Soil moisture content

The mean gravimetric soil moisture content for all paddocks was lowest in autumn and highest in winter ($P<0.001$, Figure 6.1). The gravimetric soil moisture content in winter was as high as 80 % and lowest in autumn, with measurements as low as 4 % (Table 6.1).

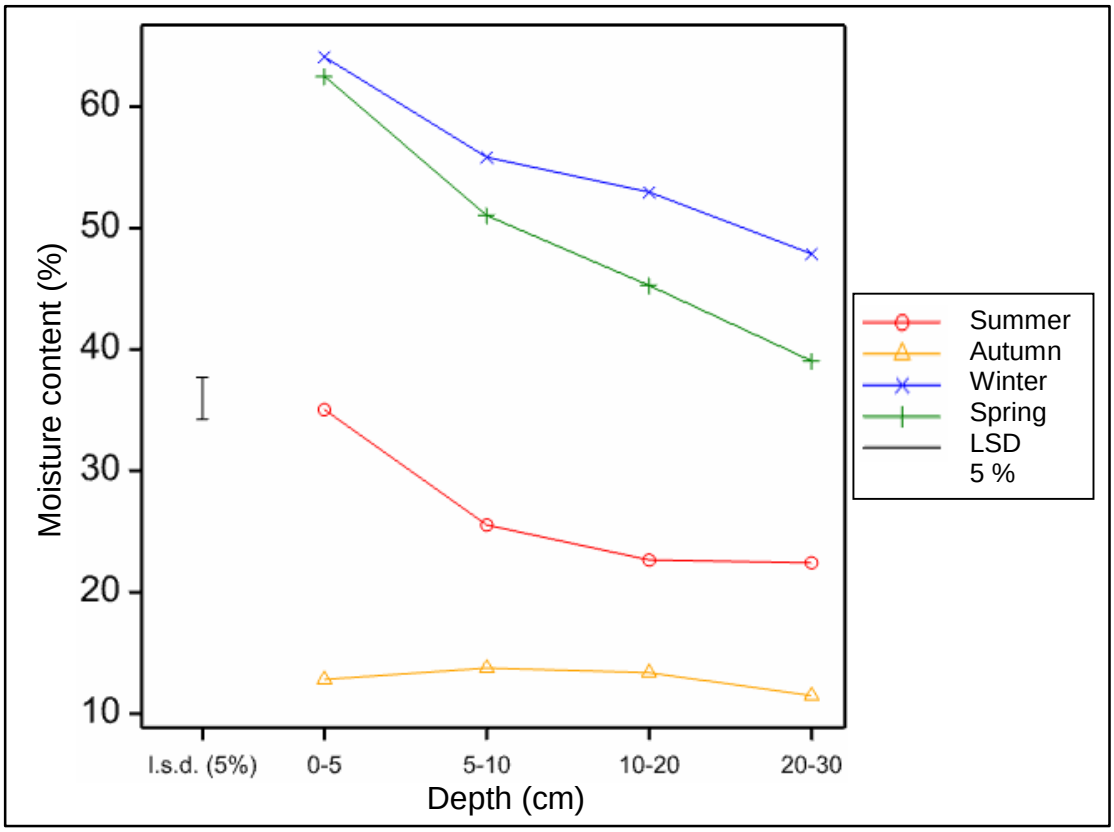


Figure 6.1: Mean gravimetric soil moisture content for all paddocks.

Table 6.1: The maximum, minimum, and mean* gravimetric moisture content (%) per depth, for each season.

Season	Depth	Minimum	Maximum	Mean
Summer (20-24th Jan)	0-5	21.77	49.73	35.05
	5-10	13.01	43.21	25.54
	10-20	8.71	39.98	22.66
	20-30	8.26	50.69	24.04
Autumn (7-10th April)	0-5	6.02	21.66	12.82
	5-10	4.11	26.40	13.76
	10-20	4.45	25.22	13.38
	20-30	4.67	22.16	11.48
Winter (14-17th July)	0-5	50.66	80.82	64.10
	5-10	44.80	67.40	55.83
	10-20	28.33	78.00	52.96
	20-30	21.28	61.69	47.88
Spring (6-12th October)	0-5	38.59	68.88	62.50
	5-10	29.91	52.64	51.04
	10-20	33.82	45.02	45.27
	20-30	19.91	40.79	39.06

*Mean of 45 samples from 15 profiles

The timing of the highest gravimetric soil moisture content measurements were consistent with the rainfall measurements (Figure 6.2); the highest total rainfall was recorded in June, when winter sampling was undertaken.

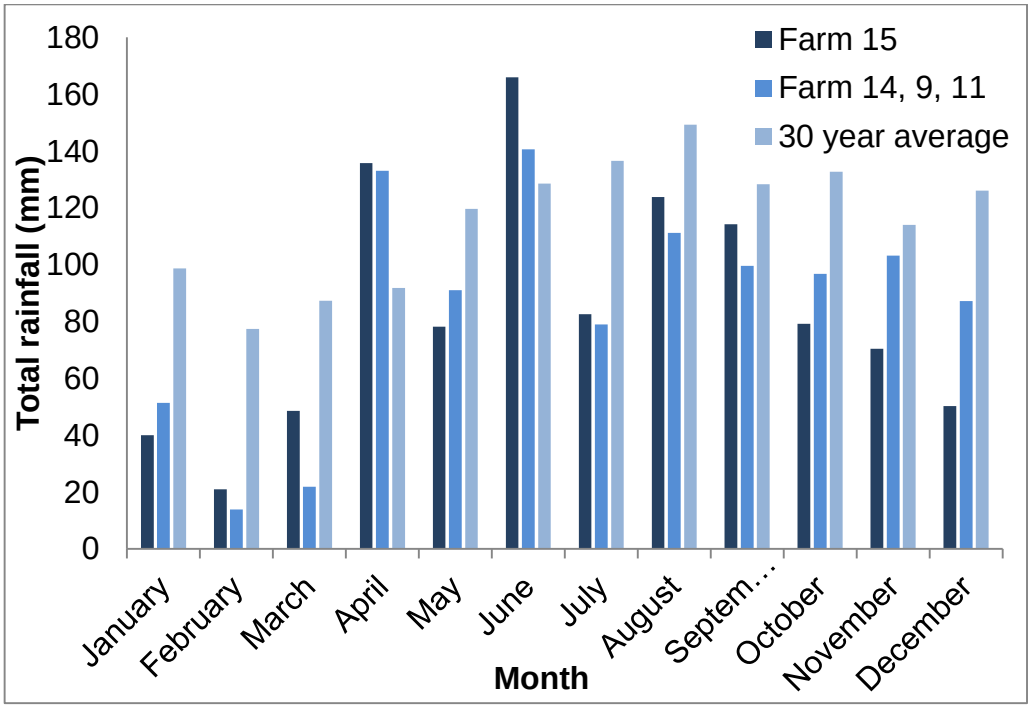


Figure 6.2: The total rainfall per month, for the studied farms (Harvest Electronics, 2015; NIWA, 2015).

The lowest total rainfall was observed during February and March, which is consistent with the lowest gravimetric moisture content measurements in the autumn sampling (undertaken in early April before the autumn rain). The gravimetric soil moisture content decreased with depth with all seasons except for autumn, which was extremely low at all depths. Compared to the 30 year average (1971-2000 from station Mangakino 2 (NIWA, 2015)), from the there was less rainfall on in 2014 in every month, with the exception of April and June.

The gravimetric soil moisture content was consistent between paddocks (Appendix 8), when grouped by pasture ages (1 year old pastures, 2-3 year old pastures, and 4+ year old pastures) there was no significant difference between pasture age groups with depth, for any seasons (Figure 6.3).

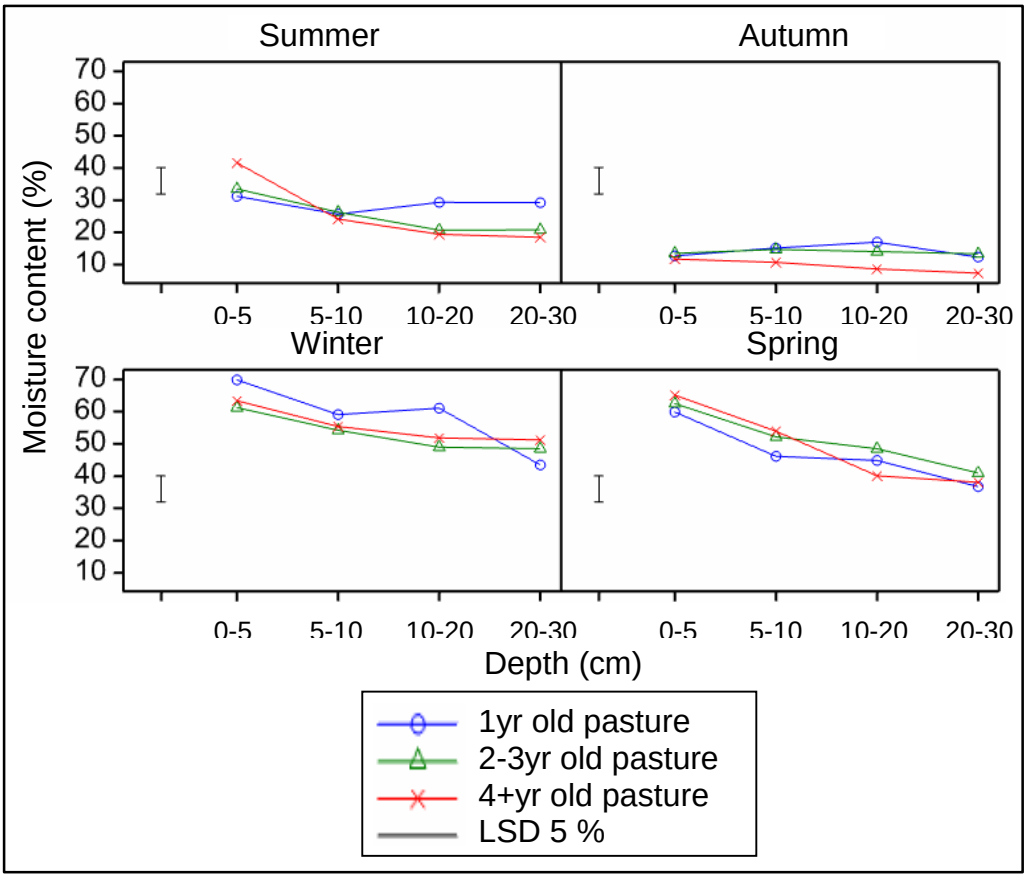


Figure 6.3: Mean gravimetric soil moisture content for each pasture age group, with season.

6.3 Dry root density

There was a consistent decrease in root density with depth, in all paddocks studied (Figure 6.4, Table 6.2). In dry root density, the majority of the root biomass was in the 0-5 cm depth, with some paddocks containing up to 95 % of the root biomass in the 0-5 cm depth (Appendix 6). There was lower root biomass present in the 5-10 cm depth than in the 0-5 cm depth, with minimal root biomass present in the 10-20 and 20-30 cm depths.

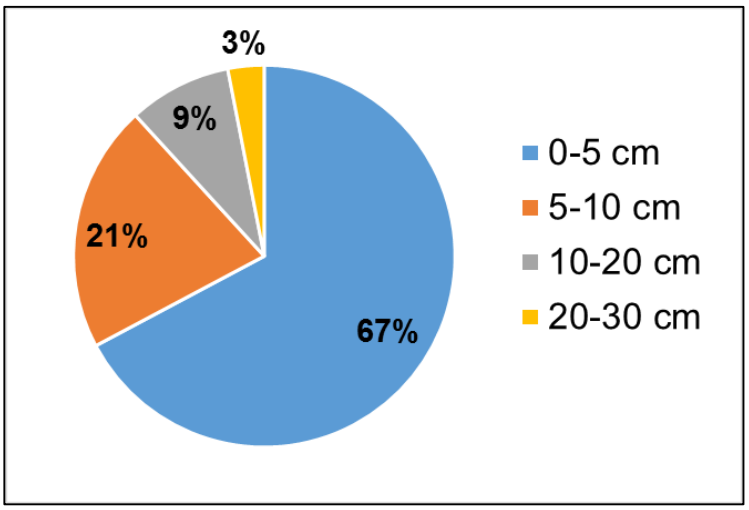


Figure 6.4: The grand mean proportion of roots in each depth, for all paddocks.

Table 6.2: The maximum, minimum and mean weights of dry root density (mg cm^{-3}) for each depth, for each season.

Season	Depth	Minimum	Maximum	Mean
Summer (20-24th Jan)	0-5	1.120	4.867	2.343
	5-10	0.122	1.264	0.653
	10-20	0.095	0.952	0.337
	20-30	0.009	0.521	0.126
Autumn (7-10th April)	0-5	0.618	4.382	2.122
	5-10	0.250	1.415	0.698
	10-20	0.032	0.946	0.319
	20-30	0.011	0.373	0.119
Winter (14-17th July)	0-5	0.848	4.928	2.233
	5-10	0.145	2.042	0.730
	10-20	0.028	1.016	0.304
	20-30	0.014	0.270	0.084
Spring (6-12th October)	0-5	1.218	2.179	2.736
	5-10	0.177	0.765	0.862
	10-20	0.099	0.122	0.265
	20-30	0.043	0.043	0.104

For dry root density, there was a significant interaction between seasons and depth in the paddocks studied ($P<0.05$) when the data was log transformed (Figure 6.5).

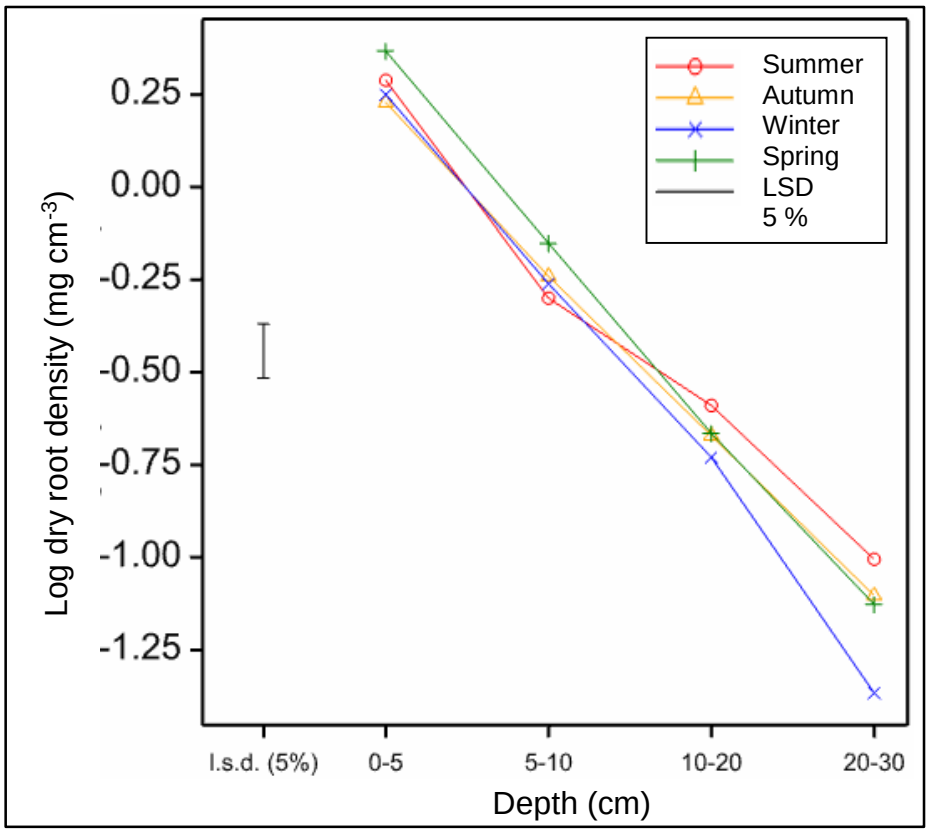


Figure 6.5: The mean dry root density for all paddocks, expressed as a log function.

The dry root density varied between paddocks in each depth, and with season, with some paddocks containing a higher root biomass than others in the 0-5 cm depth (Appendix 8). When the paddocks were grouped based on pasture age there were no significant differences in the mean dry root density of the pasture age groups with depth, or season (Figure 6.6).

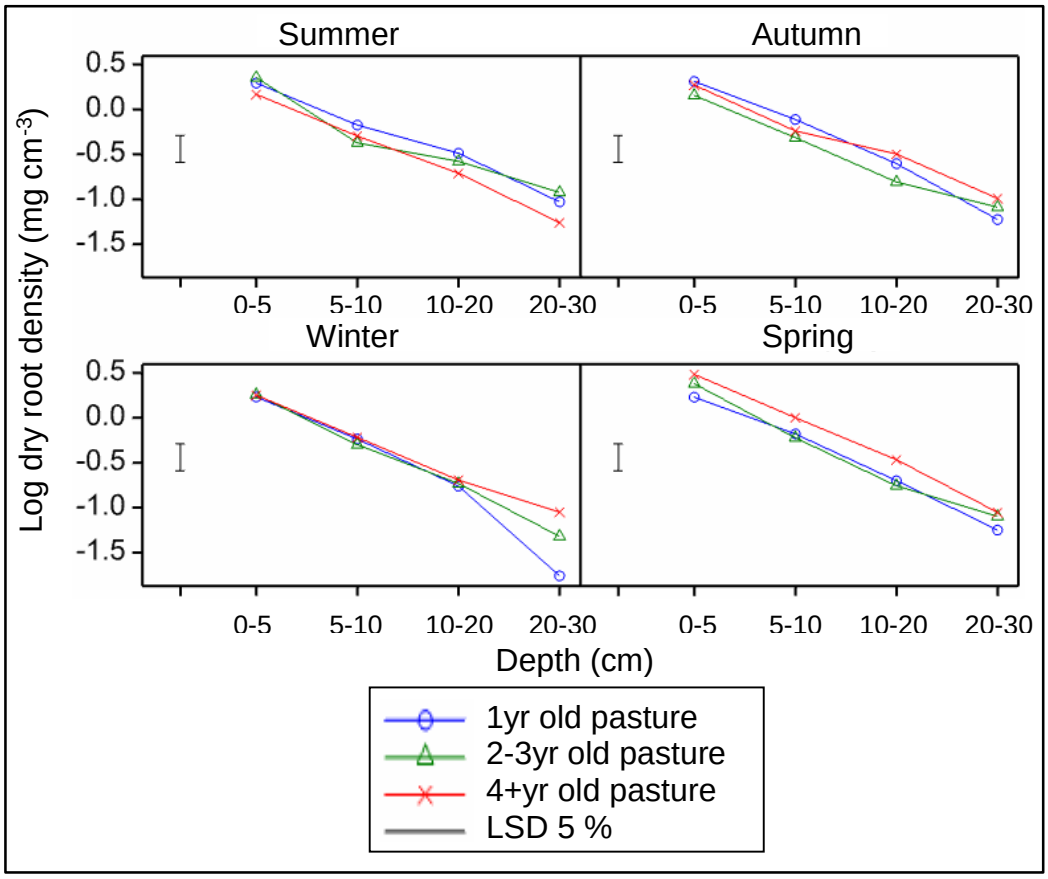


Figure 6.6: The mean dry root density for each pasture age group, for each season, expressed as a log function.

6.4 Soil dry bulk density

Soil dry bulk densities were uniformly low (in range 0.550 - 0.992 g cm^{-3}), and were consistently lowest in the 0-5 cm depth. For the soil dry bulk density there was a significant interaction between depth and season (P=0.002, Figure 6.7). The mean soil dry bulk density across all paddocks was higher in the 5-10 cm depth than in the 0-5 cm depth, in every season. The lower (10-20 and 20-30 cm) depths had soil dry bulk densities that were intermediate between those of the 0-5 and 5-10 cm depths. The mean soil dry bulk density was highest during autumn for the 0-5, 5-10 and 10-20 cm depths; however it was the lowest in the 20-30 cm depth in autumn.

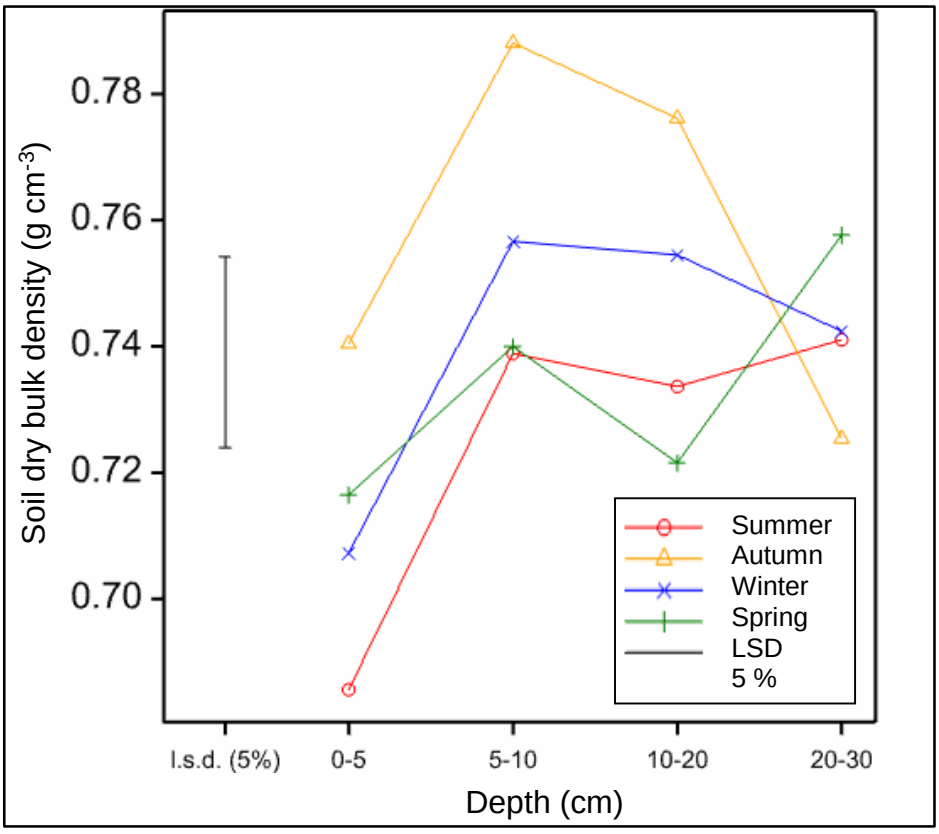


Figure 6.7: The mean soil dry bulk density for all paddocks.

For the soil dry bulk density, although there was a significant interaction between depth and season, the means of each depth for each season were not variable (Table 6.3). The mean soil dry bulk densities were within a relatively small range (0.69 – 0.79 g/cm^3), so the variation in soil dry bulk density was considered not to be of great practical significance.

When comparing individual paddocks, there was a lot of variation within paddocks (Appendix 8), with some paddocks showing an increase in the soil dry bulk density with depth, and others displaying approximately the same soil dry bulk density with depth.

Table 6.3: The maximum, minimum and mean soil dry bulk density (g cm^{-3}) for each depth, and each season.

Season	Depth	Minimum	Maximum	Mean
Summer (20-24th Jan)	0-5	0.59	0.77	0.69
	5-10	0.64	0.86	0.74
	10-20	0.62	0.88	0.73
	20-30	0.62	0.92	0.74
Autumn (7-10th April)	0-5	0.63	0.85	0.74
	5-10	0.65	0.96	0.79
	10-20	0.55	0.95	0.78
	20-30	0.57	0.90	0.73
Winter (14-17th July)	0-5	0.55	0.80	0.71
	5-10	0.62	0.86	0.76
	10-20	0.63	0.99	0.75
	20-30	0.60	0.97	0.74
Spring (6-12th October)	0-5	0.60	0.65	0.72
	5-10	0.59	0.62	0.74
	10-20	0.56	0.56	0.72
	20-30	0.55	0.55	0.76

When the paddocks were grouped based on pasture age there was no significant difference in the mean dry soil bulk density of the pasture age groups with depth, or with season (Figure 6.8), hence the age of the pasture did not correlate with the soil dry bulk density.

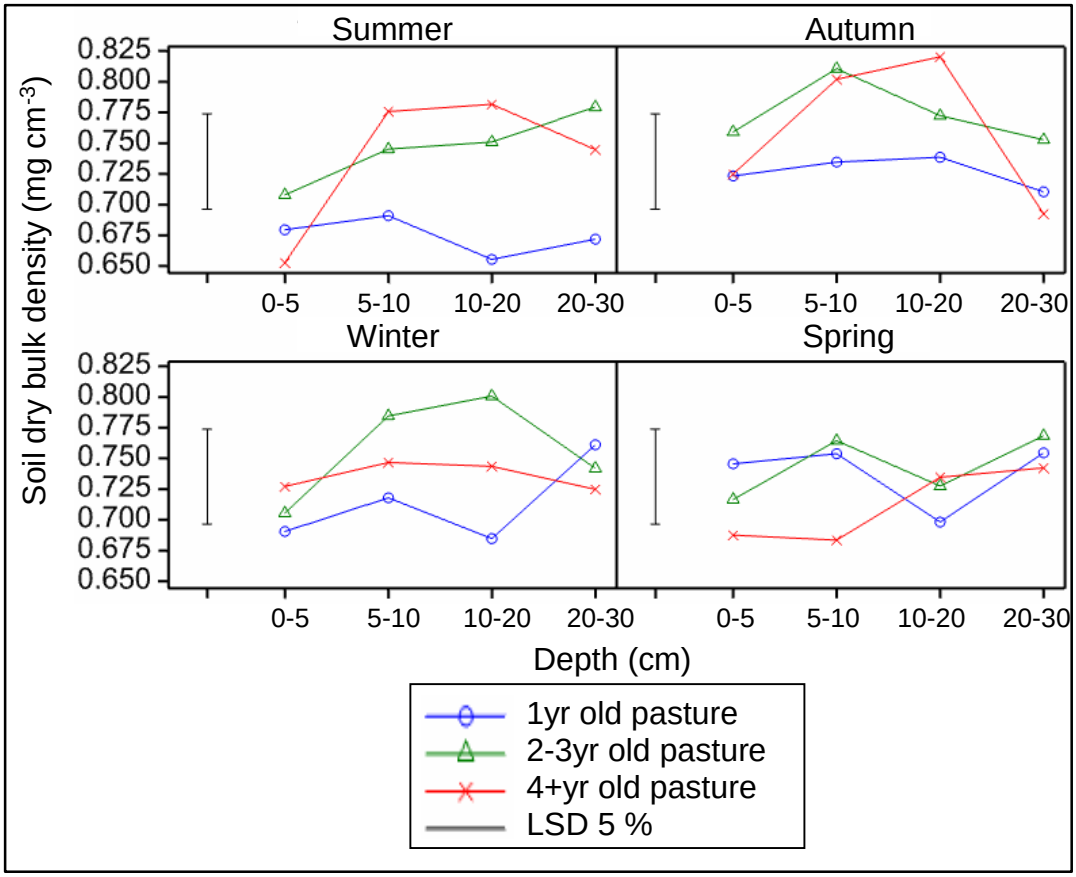


Figure 6.8: Mean soil dry bulk density for each pasture age group, for each season, and each depth.

6.5 Penetration resistance

The mean penetration resistance for all paddocks was lowest in the 0-5 cm depth and was consistently higher in the 10-20 cm depth. The 20-30 cm depth had approximately the same penetration resistance as the 10-20 cm depth (Figure 6.9). The largest difference in penetration resistance occurred between the 0-5 and 5-10 cm depths. The trends were consistent for each season. The highest mean penetration resistance measurements were measured in autumn (when the soil was driest), with maximum values such as 38, and lowest in the winter and spring with minimum values as low as 0.1 (Table 6.4).

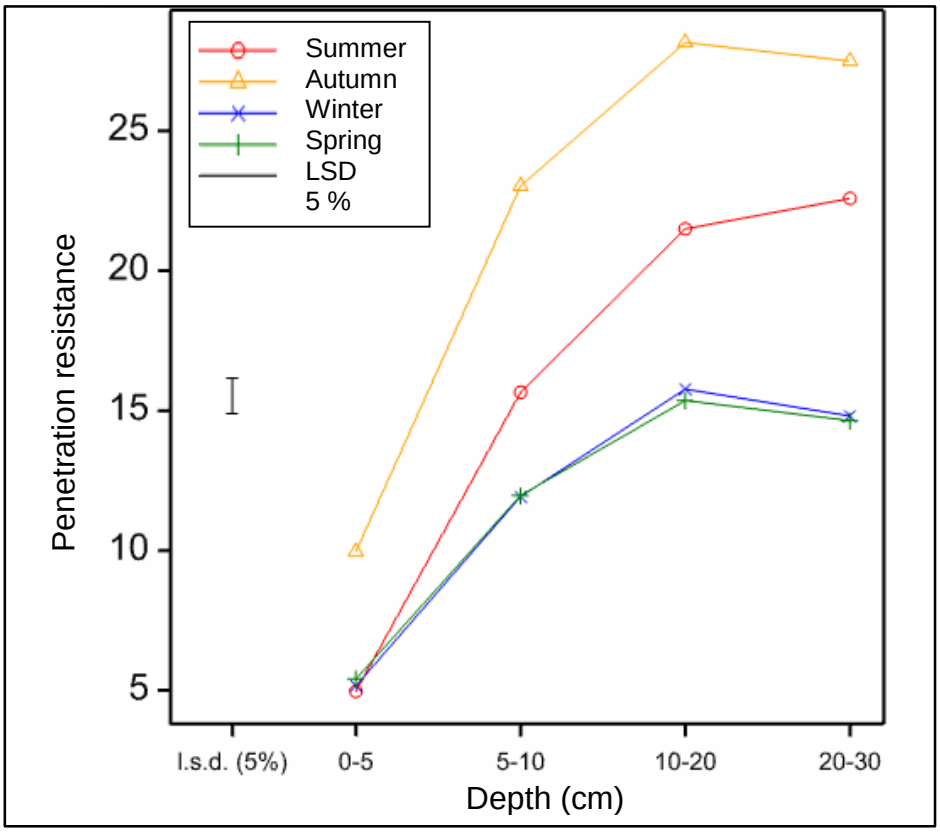


Figure 6.9: Mean penetration resistance for all paddocks.

When grouped into pasture ages, there were no significant differences in the penetration resistance with pasture age at any depth (Figure 6.9) implying that there was no relationship between pasture age and penetration resistance.

Table 6.4: The maximum, minimum and mean measurements of penetration resistance at each depth, for each season.

Season	Depth	Minimum	Maximum	Mean
Summer (20-24th Jan)	0-5	0.9	17.1	5.0
	5-10	10.3	24.9	15.7
	10-20	11.9	34.6	21.5
	20-30	11.9	37.3	22.6
Autumn (7-10th April)	0-5	3.5	17.0	10.0
	5-10	13.9	36.3	23.0
	10-20	19.0	38.8	28.2
	20-30	16.1	38.0	27.5
Winter (14-17th July)	0-5	0.1	9.1	5.2
	5-10	1.8	17.6	11.9
	10-20	10.8	22.9	15.8
	20-30	8.9	26.0	14.8
Spring (6-12th October)	0-5	2.0	5.4	5.4
	5-10	4.2	13.6	12.0
	10-20	7.8	19.2	15.4
	20-30	8.8	17.8	14.6

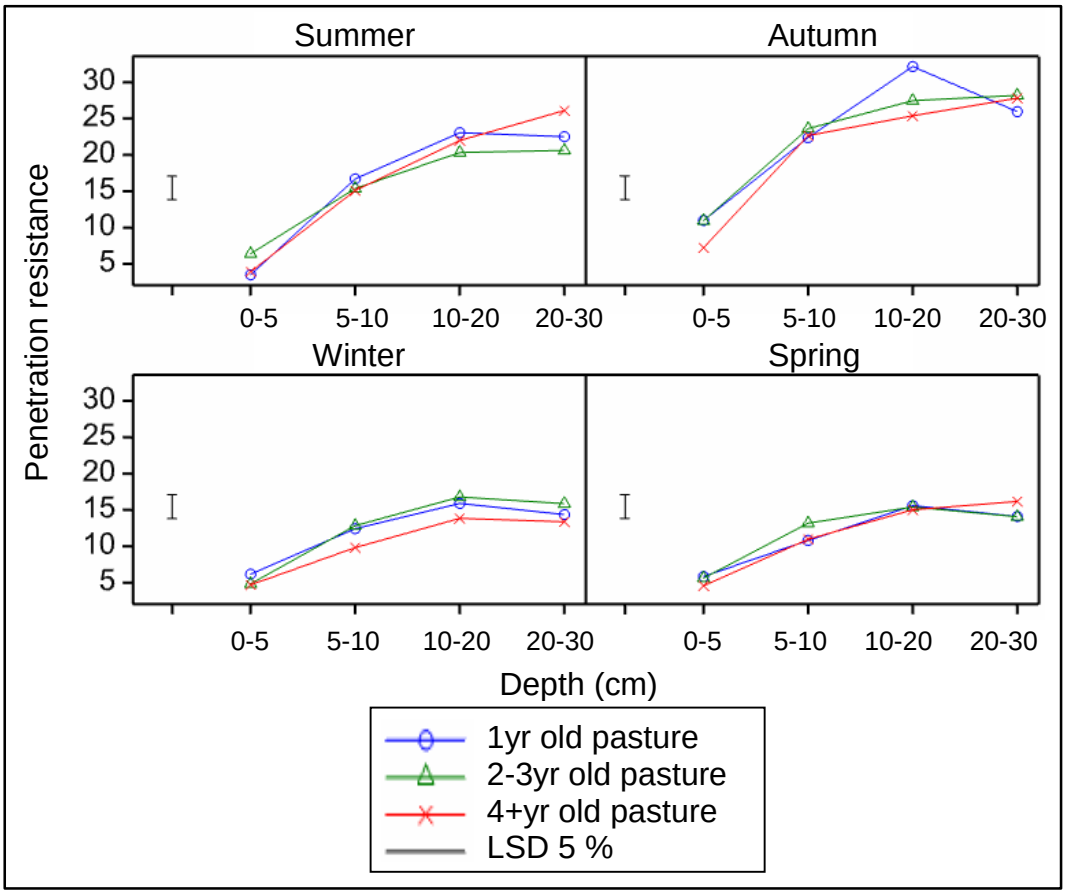


Figure 6.10: The mean penetration resistance for each pasture age group, for each season, at each depth.

6.6 Soil Macrofauna

Monitoring the soil macrofauna in the topsoil revealed some seasonal and paddock differences. Grass grub populations were low throughout the year, with just a few paddocks recorded as having between 1-3 grass grubs per 20 x 20 x 20 cm square of topsoil (Appendix 7). There was no observed increase in the populations over the summer/autumn period which is when populations of grass grub are expected to be at their highest. Black beetle populations were also low, with only a few seen in the field throughout the year.

Earthworm populations in the topsoil changed seasonally. In most paddocks studied, no earthworms were recorded from the 20 x 20 x 20 cm square of topsoil in summer and autumn. Earthworm populations were higher in the wetter seasons, with a mean of 6.8 worms in each 20 x 20 x 20 cm square of topsoil for both winter and spring.

6.7 Discussion

The soil moisture content was fairly consistent across all paddocks at any one time. Soil moisture varied greatly between seasons in response to rainfall. During autumn, when the gravimetric soil moisture contents were lower, the penetration resistance and the soil dry bulk density were both at their highest. In winter and spring, the soil moisture increased, and the penetration resistance and bulk density were lower.

Statistical analyses were conducted such as a REML (restricted maximum likelihood) variance components analysis, with paddocks as random effects, to establish if there were any significant correlations between the variables. Trellis plots are presented (Appendix 8) which show the significant relationships between the variables compared with each other (Table 6.5) for each individual paddock. The P-values presented are the mean relationship across all paddocks, and the slope shows whether there was a positive or negative relationship.

Table 6.5: Slopes and P-values for the relationships between different soil parameters, from REML analysis with paddock as a random effect for each soil depth range across seasons.

Depth (cm)	Y	X	Slope	P-value
0-5	Penetration resistance	Dry root density	0.26	0.582
	Soil dry bulk density	Dry root density	-0.01	0.164
	Soil dry bulk density	**Penetration resistance**	**0.01**	**<0.001**
	Moisture content	**Penetration resistance**	**-2.48**	**<0.001**
	Moisture content	**Soil dry bulk density**	**-88.65**	**0.044**
5-10	Penetration resistance	Dry root density	-3.52	0.071
	Soil dry bulk density	Dry root density	-0.012	0.561
	Soil dry bulk density	**Penetration resistance**	**0.003**	**0.012**
	Moisture content	**Penetration resistance**	**-2.07**	**<0.001**
	Moisture content	**Soil dry bulk density**	**-91.01**	**0.005**
10-20	**Penetration resistance**	**Dry root density**	**9.92**	**0.017**
	Soil dry bulk density	Dry root density	0.08	0.091
	Soil dry bulk density	**Penetration resistance**	**0.003**	**0.003**
	Moisture content	**Penetration resistance**	**-1.88**	**<0.001**
	Moisture content	**Soil dry bulk density**	**-84.94**	**0.001**
20-30	Penetration resistance	Dry root density	-1.90	0.867
	Soil dry bulk density	Dry root density	0.22	0.873
	Soil dry bulk density	Penetration resistance	0.0004	0.793
	Moisture content	**Penetration resistance**	**-1.35**	**<0.001**
	Moisture content	**Soil dry bulk density**	**-44.13**	**0.054**

There was a significant positive relationship of soil dry bulk density on penetration resistance in all depths except 20-30 cm (Table 6.5). The general relationship across all paddocks was that penetration resistance was higher when the soil dry bulk density was higher. The penetration resistance was higher at lower moisture contents at all depths ($P<0.001$. A correlation between moisture content and soil dry bulk density was also observed in all depths, which was a negative relationship, which showed the moisture content was higher in lower dry bulk density soils. This reflects the water holding capacity of the soil, as there is less pore space in a high bulk density soil, and thus lowers moisture holding capacity.

A relationship of penetration resistance on dry root density was observed in the 10-20 cm depth only. There were no significant relationships of the soil dry bulk density and dry root density at any depths. The paddocks were grouped based on pasture age, and a REML analysis was conducted, but showed that pasture age had no significant correlation with the soil parameters measured.

The relationship between low gravimetric soil moisture content, higher penetration resistances and higher soil dry bulk densities were expected, as soil became harder and more compacted as it lost moisture. Increased penetration resistance in compacted soil can reduce the downward growth of roots (Crush & Thom, 2011; Becel *et al.*, 2012). It is therefore, possible that at the 5-10 cm depth, where there was a relatively high penetration resistance and higher bulk density, the 5-10 cm layer may have acted as a barrier to root growth.

Although the relationships between soil parameters (gravimetric soil moisture, soil dry bulk density, dry root density and penetration resistance) were significant, they are overall seasonal trends from the 15 paddocks studied. The positive or negative relationships established from the REML analyses are not necessarily depicted in every paddock, which can be observed in the trellis plots (Appendix 8). This shows that there is a lot of

variability between each paddock. The P-values presented represent the overall trends of the 15 paddocks studied.

The soil dry bulk density was variable across paddocks and with depth. The variability was probably due to the nature of the soil, as there were varying quantities and sizes of pumice clasts throughout the soil profile. Although there was a slight difference in the soil dry bulk density with season, this is of little practical significance, as the differences in soil dry bulk density were within the range of expected values for pumice soils, which are generally less than 1.0 g/cm^3 throughout the profile (Read, 1974).

Black beetle was rarely seen throughout the trial, and grass grub was present in very low numbers. It is assumed that grass grub populations were too low to be contributing to pasture pulling, however one sample in each paddock for each season (maximum number observed was 3 at any one site) may have prevented the population size of grass grub from being accurately estimated. Earthworm populations were highest in the topsoil during winter, which correlated with higher soil moisture conditions. Earthworm populations are generally low in Pumice Soils due to the coarse texture of the soil, which makes it susceptible to droughts (Landcare Research, 2014).

Paddock 149 was cultivated after autumn sampling was undertaken, so the soil data from the winter and spring sampling were removed from the statistical analyses. Soil measurements for paddock 149 were taken during the winter and spring trial however, and showed much lower bulk density and penetration resistance measurements in all sampling depths (from 0-30 cm), which is consistent with the effects of ploughing.

6.8 Summary and conclusions

- In each paddock that was monitored for pasture pulling, soil parameters were monitored to examine if they changed seasonally, and establish if there was any relationship between soil properties and pasture pulling (Chapter 7). The soil properties measured were; gravimetric soil moisture content, dry root density, soil dry bulk density, penetration resistance, and presence of soil macrofauna. Measurements were undertaken at four depths (0-5, 5-10, 10-20 & 20-30 cm) in January, April, July, and October 2014.

- The gravimetric soil moisture content was highest in the winter and spring when rainfall was higher, and lowest in the autumn after the area had experienced a drought. The gravimetric soil moisture content decreased with depth in all seasons.

- The soil penetration resistance was highest in autumn and lowest in winter/spring. The penetration resistance generally increased with depth, but the increase was most prominent between the 0-5 and 5-10 cm depths.

- The soil dry bulk density was variable, and generally increased with depth, but the differences were of little practical significance as the measurements were within the range of that expected for a Pumice Soil (>1 g/cm^3).

- The dry root density decreased with depth, with a mean of 65 % of the root biomass present in the top (0-5 cm) depth.

- When the paddocks were grouped based on pasture age, and the means compared for each soil parameter, there was no significant difference between the pasture age groups and any soil parameter measured.

- When soil moisture levels were low, the penetration resistance and bulk density was at its highest P<0.001).
- Penetration resistance was higher when soil dry bulk density was higher (P<0.01) in the 0-5, 5-10 and 10-20 cm depths.

- Black beetle was rarely seen throughout the experiment, and low grass grub populations were present, with a maximum of 3 seen in a sample. Earthworm populations were higher in the topsoil during winter, than at other times, which correlated with increased soil moistures.

Chapter 7 - General Discussion and Conclusions

7.1 Introduction

This chapter reviews the results of the soil sampling and discusses how it influences the severity of pasture pulling, and therefore the implications of this research. Experimental limitations identified from the investigation are discussed and recommendations are provided and opportunities for future research are identified.

7.2 Relationship between pasture pulling and soil parameters

Statistical analyses were conducted to establish if there were relationships of pasture pulling on the soil parameters measured. To establish this, a REML variance components analysis was undertaken, with paddocks as random effects, investigating the significance between square root total pulls for each season, and the seasonal mean for each soil parameter at each depth (Table 7.1).

There was a negative relationship of pasture pulling on dry root density in the 0-5 cm depth, which shows an overall trend that when pasture pulling numbers are higher, dry root density in the 0-5 cm depth was lower. The lower root biomass in the 0-5 cm depth during dry spells could be contributing to a higher amount of pulling, due to the pasture not having as much anchorage.

Table 7.1: Slopes and P-values for the relationship of square root total pulls on soil parameters, from REML analysis with paddock as a random effect for each soil depth range across seasons.

Depth(cm)	Soil parameter (x)	Slope	P-value
0-5	Penetration resistance	0.005	0.815
	Soil dry bulk density	0.349	0.809
	Moisture content	**-0.0112**	**0.005**
	Dry root density	**-0.168**	**0.046**
5-10	Penetration resistance	0.028	0.074
	Soil dry bulk density	0.199	0.882
	Moisture content	**-0.013**	**0.005**
	Dry root density	-0.337	0.161
10-20	**Penetration resistance**	**0.0378**	**0.005**
	Soil dry bulk density	0.735	0.515
	Moisture content	**-0.011**	**0.022**
	Dry root density	-0.261	0.541
20-30	**Penetration resistance**	**0.0259**	**0.022**
	Soil dry bulk density	-0.298	0.764
	Moisture content	-0.0104	0.061
	Dry root density	0.281	0.787

There was a significant relationship of pasture pulls on moisture content in the 0-5, 5-10 and 10-20 cm depths ($P<0.05$). The general trend observed was that more pulling occurred when gravimetric soil moisture contents were low. This relationship was also observed by Thom *et al.* (1998), who observed pasture pulling to be more severe when pasture suffered from water stress. Low soil moistures were also significantly correlated with higher soil dry bulk density and a higher penetration resistance, which could suggest a more compacted soil which roots could not penetrate, possibly reducing the anchorage of the pasture in the soil.

A positive relationship was observed of pasture pulling on penetration resistance in the 10-20 and 20-30 cm depths ($P<0.05$) with an overall trend of the penetration resistance in the 10-20 and 20-30 cm depths higher when pasture pulling numbers were higher. A higher penetration from 10 cm depth onwards may have contributed to increased pasture

pulling, as the pasture roots were less able to penetrate deeper into the soil profile.

There were no relationships between the mean number of pulls and soil parameters when the paddocks were grouped by pasture age. Thus although anecdotal evidence reports worse pulling in younger pastures, we did not find strong evidence for that assertion.

7.3 General discussion

Pasture pulling did not occur in only one period of the year; it was observed in paddocks with a range of pasture ages, throughout the year. However, it was more severe in the summer and autumn, which correlated with low gravimetric soil moisture content in the 0-5, 5-10 and 10-20 cm depths. Mangakino has dry, hot summers, and cold wet winters. In February and March 2014 the area had a drought, which is evident in the moisture content data for each season (Figure 6.1). Pasture pulling was also observed by Thom *et al.* (1996) and Bahmani *et al.* (2001) to be worse when soil moisture levels were low.

The moisture content correlated negatively with pasture pulling, but this does not necessarily mean it is a direct cause of pasture pulling. The occurrence of higher rates of pasture pulling when soil moistures were lower could be a coincidence, because it is occurring at a time of the year when soil moisture content is going to be low regardless. Other parameters that were not measured might have been affecting the severity of the pasture pulling, with low moisture content coinciding at the same time.

The moisture content did correlate with penetration resistance at every depth, with the overall trend being that the penetration resistance was highest when soil moistures were low. There were correlations between pasture pulling and penetration resistance in the 10-20 and 20-30 cm depth, with the general trend being that pasture pulling rates were high

when penetration resistance at the 10-20 and 20-30 cm depths was high. There was not a significant relationship of pasture pulling on penetration resistance at the 0-5 and 5-10 cm depths, which could be explained by there being a larger variability in the penetration resistance at these depths, due to it being closer to the soil surface and there being more root interaction with the soil (soil may be less compacted).

The relationship between pasture pulling and penetration resistance provides evidence of compaction preventing pasture roots from penetrating deeper into the soil profile. Pumice soils can be susceptible to compaction on loading (Hewitt, 2010), and increased penetration resistance can prevent the downward growth of roots (Crush & Thom, 2011). Houlbrooke (1996) also observed that pasture pulling may be related to increased soil compaction measured by penetration resistance between 7 and 10.5 cm depth. The clumps appear to be pulled at this depth, and it is possible that the compacted layer acts as a barrier to root growth. Observations were also made in the field of a platy soil structure in the 5-10 cm depth in many paddocks (Section 4.4, Figure 4.5). Read (1974) stated that where there is compaction of pasture topsoil, it may lead to a massive or platy soil structure.

There was a significant negative relationship of pasture pulling on dry root density in the 0-5 cm depth, with higher numbers of pulling recorded when dry root density in the 0-5 cm depth was lower. During the drought, much of the pasture present in the monitored paddocks became very dry, and some died off. It is possible that the roots of the pasture also died, which may have accentuated pasture pulling in some of the paddocks which also contained a lower root biomass than other paddocks.

The paddocks monitored for pasture pulling at Pouakani dairy farms were on Orthic Pumice Soil, with a sandy loam texture throughout, and various sizes and quantities of pumice clasts. The nature of the soil texture meant that soil dry bulk density measurements were quite variable, although they

were within range of typical soil dry bulk density values for a Pumice Soil which are less than 1.0 g/cm^3 (Read, 1974). There was no correlation between pasture pulling and soil dry bulk density, which may be attributed to the soil variability.

The pH measurements taken at the commencement of the study were within the accepted levels for a typical dairy pasture. Although soil fertility was not measured, fertiliser was added regularly to the soil surface to maintain a high soil fertility. Therefore there was a generous supply of nutrients at the soil surface, which pasture roots do not need to search deep for. With some of the paddocks measured up to 80% of the root biomass was present in the 0-5 cm depth, having generous nutrients at the soil surface may also contributing to the roots not penetrating deeper. There is also a much higher organic matter content in 0-5 cm depth compared to the other depths, which could be another reason for the shallow rooting depth.

Pasture age did not have a significant relationship with any soil characteristics in the paddocks monitored at Pouakani dairy farm. There were no significant interactions in the soil parameters with depth or season, when the paddocks were grouped based on pasture age. There were no significant relationships between the total numbers of pasture clumps pulled in each pasture age group, but for the pasture pulling, there was a significant interaction with pasture age group, and assessment date. There were different trends in the rate of pulling throughout the year for each pasture age group.

Overall, the pasture pulling was not severe at Pouakani Dairy farms in 2014. At other sites in the region, much more severe pasture pulling was observed. At severe pasture pulling sites, high numbers of grass grub were also observed. As low numbers of grass grub were recorded at Pouakani Dairy farms in 2014, particularly in autumn when populations of grass grub are expected to be at their highest, and it is recommended that in each 20 cm spade square four or more grass grubs present indicate

high populations (Zydenbos *et al.*, 2013). It is therefore concluded that grass grub did not affect the severity of pasture pulling at Pouakani dairy farms.

Observations were made in the field during pasture pulling assessments of the way pasture was growing in small clumps, which were easily dislodged from the soil by grazing livestock. The paddocks which had distinct clumps of pasture were often surrounded by areas of bare ground. Pasture clumps surrounded by bare ground were commonly observed in paddocks in which the pasture had been sown via direct drill, with clearly defined rows of pasture, in small clumps (Figure 7.1).

Figure 7.1: Pasture that has been direct drilled, in which pasture has grown in clumps, in clearly defined rows.

Although the comparison between direct drilled pasture and other methods, such as broadcast sown pasture was not undertaken, observations suggested that direct drilling pasture might have been a contributing factor to the likelihood of pasture to be pulled.

It was observed that there was an increase in pasture diversity with pasture age. All pasture pulls recorded were grasses, not one pull was dominated by clover, weeds or chicory. Ryegrass has been reported to struggle to adapt to growing roots through a compacted soil due to the fine

roots it possesses (Crush & Thom, 2011) . Crops such as chicory have a deeper rooting depth (Skinner, 2008), so could withstand grazing events better than grasses such as ryegrass. Burggraaf and Thom (2000) observed pasture pulling to be less severe when clover was present in the sward. However, the quantity of root biomass present in the 0-5 cm depth did not change between paddocks of different pasture ages. Therefore, the data does not support that root biomass depends on pasture species composition, because no significant differences were observed between paddocks of different pasture ages.

A combination of limited rooting depth, lower root density in the 5-10 cm depth, increased compaction with depth, less cohesive soil when it has low moisture, and the incidence of pasture growing in clumps, may have all contributed in the occurrence of pasture pulling. This study has not discovered one sole cause of pasture pulling at Pouakani dairy farms, but has identified a number of soil characteristics that may be having an influence.

7.4 Experimental limitations

Several experimental limitations in this study have been identified. The resources and time available meant there was a restriction on the number of paddocks monitored, and also reps per paddock. There is a lot of variability in the data. Soil macrofauna numbers were low. Due to limited sample numbers (15 per season), the size of the soil macrofauna population might have been inaccurately described. With more reps per paddock, and possibly more sampling events throughout the year, a better representative sample may have been obtained.

The number of quadrats and transects per paddock used to measure the amount of pasture being pulled did not necessarily depict the amount of pulling in the paddock. Often there would be quite a bit of pulling observed in some paddocks, but it wasn’t always appearing in the quadrats that had been set to record the pulling. With more than one transect per paddock

and therefore more quadrats, a more representative number of pulled clumps per paddock might have been obtained.

The pastures aged 4+ years were intended to be pastures which were established, and therefore not expected to suffer high amounts of pulling. The 4+ year old pastures were intended to be "control" paddocks to compare with the younger pasture paddocks, which were expected to pull. However, all paddocks in the trial pulled, so the 4+ aged pasture paddocks were not suitable as "control" paddocks, therefore there was no control paddock to compare the other paddocks to, rather there was just a continuum of more and less pulling between paddocks.

Paddocks were not grazed as much during the winter period as pasture growth rate was slower and some of the herd was taken off-site to graze at another farm. Thus over the winter period (June-August) paddocks were assessed less frequently, and less pulling was observed. This could have confounded the results as it is not known if the pulling was lesser over this period because of decreased grazing events, or the change in season had an effect on the severity of pasture pulling.

There was a lack of control over the management of the paddocks due to the experiment being run on a working farm. Some paddocks were treated differently on occasions which could not be controlled by the researcher. For example, it was intended that all paddocks were going to have the same management practices applied to them for the whole year. This was not the case however, as some paddocks were sprayed and/or re-sown during the monitoring programme, some paddocks were cultivated and sown into crops, some paddocks were cut for silage, rather than being grazed, and on occasions the animals were given supplementary feed whilst they were grazing in some paddocks. This made it harder to compare the paddocks as the same, and the data from some paddocks could not be used. In a future study, it would be best to have paddocks

which were not going to be altered significantly or treated differently to the other paddocks, so they could be more comparable to each other.

7.5 Recommendations and future research

On the completion of this research several opportunities for future research into pasture pulling have been recognised. Factors to be considered to help minimise the severity of pasture pulling include:

- Pasture species composition
- Pasture establishment
- Cultivation

Observations were that the more diverse pastures pulled less, and paddocks which contained chicory had no chicory pulled from the soil. Crops such as chicory have taproots which penetrate deeper into the soil profile, which provide a better anchor for the plant. Thus, a pasture that has a more diverse sward, such as other grass species, or species such as chicory and plantain, could help in minimising pasture pulling.

In many cases the pasture that was pulled at Pouakani dairy farms was sown and grew in small clumps, which were easily removed from the soil as cows grazed the paddock. The majority of the paddocks studied had pasture sown using the direct drilled method, in which pasture is sown in defined rows. If the pasture was sown more evenly across the paddock, without the gaps between each row such as in broadcast sowing, the pasture roots could perhaps grow more intertwined and provide a better anchor when the paddock is being grazed.

Cultivating or subsoiling the paddock to break up the compacted soil at depths of 5 cm onwards may help to prevent pasture pulling. Breaking up the compacted layer via cultivation could allow pasture roots to penetrate deeper into the soil profile, thus providing a better anchor for the plant.

There is still a lot of research that can be conducted on the causes of pasture pulling. One opportunity would be to conduct a controlled

experiment that examined the differences in pulling from various pasture swards. An example of a controlled experiment would be to split a paddock in half and sow two different types of pasture in each. Applying the same management practices, and having the same intensity of grazing can enable only the effect the pasture species has on the severity of pulling to be observed. Controlled experiments could also be used to investigate the effects on pasture pulling of:

- Differing soil moisture contents
- Broadcast vs drilled pasture sowing techniques
- Cultivation before re-sowing pasture vs non-cultivation before re-sowing pasture
- Compare the rooting depth of different grass species

7.6 Review of hypotheses

It is important to refer back to the original hypotheses set prior to the commencement of the study, and to reflect on whether they are to be accepted or rejected.

Hypothesis one - soil compaction is limiting the downward expansion of roots.

Soil parameters measured to address this hypothesis were soil dry bulk density, penetration resistance, and dry root density. The analyses showed correlations between pasture pulling, soil dry bulk density, penetration resistance, and dry root density. The rooting depth was possibly limited by the higher compaction (as evidenced by higher penetration resistance) of the soil at the 5-10 cm depth. Overall, the data supports the hypothesis that soil compaction is limiting the downward expansion of roots.

Hypothesis two - pasture pulling occurs when there is severe damage to roots as a result of grass grub infestation.

Grass grub populations were low in the paddocks studied, and thus did not appear to be a major cause of pulling in this area. There was no significant interaction between pasture pulling and grass grub or black beetle populations. The data does not support hypothesis two.

Hypothesis three – more pasture pulling occurs when soil has lower moisture conditions.

There were correlations between moisture content and mean pasture pulling, which showed that pasture pulling was most common when soil moisture levels were low. There was also a correlation between moisture content and penetration resistance, and moisture content and soil dry bulk density at every depth, which implies that the soil may have been more compact when soil moistures were low, preventing the pasture from obtaining a deeper rooting depth. Overall, the data supports hypothesis three.

Hypothesis four - Younger pastures are more prone to pasture pulling.

Pulling was anecdotally reported to occur mainly in autumn one year after new grass has established. However, there was no significant relationship between the age of pasture and the number of pulls. When the clump sizes of pasture pulled were compared, there was a significant difference in the number of small and medium sized clumps of pasture pulled and the age of pasture, with assessment date, with less medium and large pulls in the older (4+ years) pastures. Hypothesis four should be rejected as the age of pasture did not influence the amount of pulling observed at Pouakani dairy farms. However, the age of pasture did effect the size distribution of the pulls in different pasture ages.

7.7 Summary and conclusions

- The overall objective was to investigate the occurrence, and establish the causes, of pasture pulling under dairy farming on Orthic Pumice Soil in the Central North Island, New Zealand.

- Pasture pulling was observed for one calendar year, in 15 paddocks of different pasture ages on Pouakani dairy farms in the central North Island of New Zealand. Pasture pulling assessments were conducted every 3 weeks if the pasture had been grazed since the last assessment, by measuring the amount and size of pasture pulls dislodged from the soil in 5 x 4m^2 quadrats per paddock. Observations were also made of the dominant pasture species in each quadrat, as well as the species of the pulled material.

- In each paddock that was monitored for pasture pulling, soil parameters were monitored to examine if they changed seasonally, and establish if there was any relationship between soil properties and pasture pulling. The soil properties measured were; gravimetric soil moisture content, dry root density, soil dry bulk density, penetration resistance, and presence of soil macrofauna. Measurements were undertaken at four depths (0-5, 5-10, 10-20 & 20-30 cm) in January, April, July, and October 2014.

- The soils in the study comprised Typic Orthic Pumice Soil, and Immature Orthic Pumice Soil. The soils were similar in all properties, with all soils exhibiting a dominant sandy loam texture with varying pumice clast contents. The pH values measured ranged between 5.2 and 6.5. No significant differences in pH were seen with depth or between paddocks.

- Pasture pulling occurred throughout the year in all paddocks investigated, but was most common during the late summer and autumn.

- The dominant pasture species observed across all paddocks was perennial ryegrass. The paddocks with older, more established pastures contained a higher proportion of other grass species and weeds.

- Only grass was pulled from the soil, other species such as clover, chicory and weeds were not pulled by grazing stock.

- The soil dry bulk density was variable, and generally increased with depth, but the differences were of little practical significance as the measurements were relatively low and within the range expected for a Pumice Soil (>1 g/cm^3).

- The dry root density decreased with depth, with a mean of 65 % and up to 80 %, of the root biomass present in the top (0-5 cm) depth.

- Factors that showed some seasonal relationship to the occurrence of pulling included; low soil moisture levels, low dry root density in the 0-5 cm depth, and higher soil dry bulk density and penetration resistances of the soil. The gravimetric soil moisture content was highest in the winter and spring when rainfall was higher, and lowest in the autumn after the area had experienced a drought. The gravimetric soil moisture content decreased with depth in all seasons.

- Pasture pulling in 2014 at Pouakani dairy farm was not observed to be strongly influenced by grass grub infestations feeding on the roots of pasture. The grass grub population numbers were

observed to be low (with none seen at most of the sites investigated), to be influencing pasture pulling. Black beetle was rarely seen throughout the experiment. Earthworm populations were higher in the topsoil during winter, than at other times, which correlated with increased soil moisture.

- Pasture root extension was observed to be restricted at the 5 cm depth, with the 5-10 cm where soil compaction appeared to be increasing. The 5-10 cm depth generally showed increased compaction with higher soil dry bulk density and penetration resistance then the surface soil.

- There were no relationships between the mean number of pulls and soil parameters when the paddocks were grouped by pasture age. Thus although anecdotal evidence reports worse pulling in younger pastures, we did not find strong evidence for that assertion.

- Overall, the pasture pulling was not severe at Pouakani Dairy farms in 2014. At other sites in the region, much more severe pasture pulling was observed.

- Overall, the data supported the hypothesis that soil compaction is limiting the downward expansion of roots, and the hypothesis that more pasture pulling occurs when soil has lower moisture conditions. The data did not support the hypothesis in which pasture pulling occurs when there is severe damage to roots as a result of grass grub infestation, or the hypothesis which stated younger pastures were more prone to pasture pulling.

- This study has not discovered one sole cause of pasture pulling at Pouakani dairy farms, but has identified a number of soil characteristics that may be having an influence, including of limited rooting depth, lower root density in the 5-10 cm depth, increased

compaction with depth, less cohesive soil when it has low moisture, and the incidence of pasture growing in clumps.

Reference List

Álvarez, E., Fernández-Marcos, M. L., Monterroso, C., & Fernández-Sanjurjo, M. J. (2005). Application of aluminium toxicity indices to soils under various forest species. *Forest Ecology and Management, 211*(3), 227-239. doi:http://dx.doi.org/10.1016/j.foreco.2005.02.044

Bahmani, I., Thom, E. R., Matthew, C., & Lemaire, G. (2001). Productivity of grazed perennial ryegrass dairy pastures from different ecotypes under nitrogen and irrigation treatments. *New Zealand Journal of Agricultural Research, 44*(2-3), 123-133. doi:10.1080/00288233.2001.9513468

Barker, G. M., Pottinger, R. P., & Addison, P. J. (1989). Population-dynamics of the argentine stem weevil (listronotus-bonariensis) in pastures of waikato, new-zealand. *Agriculture Ecosystems & Environment, 26*(2), 79-115. doi:10.1016/0167-8809(89)90021-2

Becel, C., Vercambre, G., & Pages, L. (2012). Soil penetration resistance, a suitable soil property to account for variations in root elongation and branching. *Plant and Soil, 353*(1-2), 169-180. doi:10.1007/s11104-011-1020-7

Blake, G. R., & Hartge, K. H. (1986). Bulk Density. In A. Klute (Ed.), *Methods of soil analysis. Part 1*. Wisconsin, United States of America: Soil Science Society of America

Blakemore, L. C., Searle, P. L., & Daly, B. K. (1987). Methods of chemical analysis of soils. *NZ Soil Bureau Scientific Report 80*

Blank, R. H., & Olson, M. H. (1988). Effect of black beetle, in association with nitrogen and summer spelling, on pasture production on sandy soils. *New Zealand Journal of Agricultural Research, 31*(4), 445-453. doi:10.1080/00288233.1988.10423440

Brock, J. L., & Kane, G. J. (2003). Variability in establishing white clover in pastures on farms. *Proceedings of the New Zealand Grassland Association, 65*, 223-228.

Burggraaf, V. T., & Thom, E. R. (2000). Contamination and persistence of endophyte‐free ryegrass pastures established by spray‐drilling, and intensively grazed by dairy cows in the Waikato region of New Zealand. *New Zealand Journal of Agricultural Research, 43*(2), 163-173. doi:10.1080/00288233.2000.9513418

Campbell, B. D., Wardle, D. A., Woods, P. W., Field, T. R. O., Williamson, D. Y., & Barker, G. M. (1996). Ecology of subtropical grasses in temperate pastures: an overview. *Proceedings of the New Zealand Grassland Association, 57*, 189-197.

Clark, D. A. (2011). Changes in pastoral farming practices and pasture persistence - a review. *Pasture Persistence - Grassland Research and Practice Series, 15*, 7-14.

Clayden, B., & Hewitt, A. E. (1994). *Horizon notation for New Zealand soils*. Lincoln, New Zealand: Manaaki Whenua Press.

Cook, A., Marriott, C. A., Seel, W., & Mullins, C. E. (1996). Effects of soil mechanical impedance on root and shoot growth of Lolium perenne L, Agrostis capillaris and Trifolium repens L. *Journal of Experimental Botany, 47*(301), 1075-1084. doi:10.1093/jxb/47.8.1075

Crush, J. R., Ouyang, L., Eerens, J. P. J., & Stewart, A. V. (2002). The growth of roots of perennial, Italian, hybrid and annual ryegrasses through a high-strength root medium. *Grass and Forage Science, 57*(4), 322-328. doi:10.1046/j.1365-2494.2002.00332.x

Crush, J. R., & Thom, E. R. (2011). The effects of soil compaction on root penetration, pasture growth and persistence. *Grasslands Research and Practice Series, 15*, 73-78.

Drewry, J. J., Cameron, K. C., & Buchan, G. D. (2008). Pasture yield and soil physical property responses to soil compaction from treading and grazing - a review. *Australian Journal of Soil Research, 46*(3), 237-256. doi:10.1071/sr07125

Drewry, J. J., Lowe, J. A. H., & Paton, R. J. (2000). Effect of subsoiling on soil physical properties and pasture production on a Pallic Soil in Southland, New Zealand. *New Zealand Journal of Agricultural Research, 43*(2), 269-277.

Drewry, J. J., Paton, R. J., & Monaghan, R. M. (2004). Soil compaction and recovery cycle on a Southland dairy farm: implications for soil monitoring. *Australian Journal of Soil Research, 42*(7), 851-856. doi:10.1071/sr03169

East, R., Kain, W. M., & Douglas, J. A. (1980). The effect of grass grub on the herbage production of different pasture species in the pumice country. *Proceedings of the New Zealand Grassland Association, 41*, 508-513.

Eerens, J. P. J., Rahman, A., & James, T. K. (2002). Optimising pasture production to minimise weed growth. *Proceedings of the New Zealand Grassland Association, 64*, 143-146.

Ennos, A. R. (1990). The Anchorage of Leek Seedlings: The Effect of Root Length and Soil Strength. *Annals of Botany, 65*(4), 409-416.

Harrison, D. F., Cameron, K. C., & McLaren, R. G. (1994). Effects of subsoil loosening on soil physical-properties, plant-root growth, and pasture yield. *New Zealand Journal of Agricultural Research, 37*(4), 559-567.

Harvest Electronics. (2015). *Wairarapa Moana weather data.* Retrieved from http://www.harvestalarms.com/w.cgi?hsn=11056&grp=Main

Hewitt, A. E. (2010). *New Zealand soil classification* (3rd ed.). Lincoln, N.Z.: Manaaki Whenua Press.

Hillel, D. (1980). *Fundamentals of soil physics*. New York: Academic Press.

Hogg, A., Lowe, D. J., Palmer, J., Boswijk, G., & Ramsey, C. B. (2012). Revised calendar date for the Taupo eruption derived by 14C wiggle-matching using a New Zealand kauri 14C calibration data set. *The Holocene, 22*(4), 439-449. doi:10.1177/0959683611425551

Houlbrooke, D. J. (1996). *Subsoiling and soil compaction effects on soil physical properties and pasture response* (Masters Thesis). University of Waikato, Hamilton, New Zealand.

Houlbrooke, D. J., Thom, E. R., Chapman, R., & McLay, C. D. A. (1997). A study of the effects of soil bulk density on root and shoot growth of different ryegrass lines. *New Zealand Journal of Agricultural Research, 40*(4), 429-435. doi:10.1080/00288233.1997.9513265

Kerr, G. A., Chapman, D. F., Thom, E. R., Matthew, C., Van Der Linden, A., Baird, D. B., . . . NZGA. (2012). Evaluating perennial ryegrass cultivars: improving testing *Proceedings of the New Zealand Grassland Association* (Vol. 74, pp. 127-135).

Landcare Research. (2014). *Soil Orders from the New Zealand Soil Classification (NZSC).* Retrieved from http://soils.landcareresearch.co.nz/contents/SoilNames_NZsoilClassification_SoilOrders.aspx#M

Lowe, D. J., & Palmer, D. J. (2005). Andisols of New Zealand and Australia. *Journal of Integrated Field Science, 2*, 39-65.

McLaren, R. G., & Cameron, K. C. (1996). *Soil science :sustainable production and environmental protection* (2nd. ed.). Auckland: Oxford University Press.

Milne, G. D. (2011). Can pasture persistence be improved through the use of non-ryegrass species? *Pasture Persistence - Grassland Research and Practice Series 15*, 157-162.

Milne, J. D. G. (1995). *Soil description handbook* (Rev. / ed.). Lincoln, N.Z.: Manaaki Whenua Press.

Mitchell, C. H., & Dickens, R. (1979). Nitrogen Fertilization and Mowing Height Effects on Tensile Strength of Bermudagrass Sod. *Agron. J., 71*(6), 1061-1062. doi:10.2134/agronj1979.00021962007100060039x

Molloy, L., Christie, Q. R., Hewitt, A. E., & New Zealand Society of Soil, S. (1998). *Soils in the New Zealand landscape: the living mantle*. Lincoln, N.Z.: New Zealand Society of Soil Science.

NIWA. (2015). *CliFlo: NIWA's National Climate Database on the Web.* Retrieved from http://cliflo.niwa.co.nz/

Oswalt, D. L., Bertrand, A. R., & Teel, M. R. (1959). Influence of Nitrogen Fertilization and Clipping on Grass Roots1. *Soil Sci. Soc. Am. J., 23*(3), 228-230. doi:10.2136/sssaj1959.03615995002300030022x

Patchett, B., Gooneratne, R., Chapman, B., & Fletcher, L. (2011). Effects of loline-producing endophyte-infected meadow fescue ecotypes on New Zealand grass grub (Costelytra zealandica). *New Zealand*

Journal of Agricultural Research, 54(4), 303-313. doi:10.1080/00288233.2011.608686

Prestidge, R. A., Vanderzijpp, S., & Badan, D. (1985). Effects of plant species and fertilisers on grass grub larvae, Costelytra zealandica. *New Zealand Journal of Agricultural Research, 28*(3), 409-417.

Prestidge, R. A., Vanderzijpp, S., & Gault, P. (1989). Effect of Argentine stem weevil on vigour of 'Grasslands Roa' tall fescue under dairying in the Waikato. *New Zealand Journal of Agricultural Research, 32*(2), 291-297.

Read, N. E. (1974). *Soil groups of New Zealand*. Wellington, N.Z.: New Zealand Society of Soil Science.

Robson, A. D. (1989). *Soil acidity and plant growth*. Sydney: Academic Press.

Schaetzl, R. J., & Anderson, S. (2005). *Soils: genesis and geomorphology*. New York: Cambridge University Press.

Schlueter, D., & Tracy, B. (2012). Sowing Method Effects on Clover Establishment into Permanent Pasture. *Agronomy Journal, 104*(5), 1217-1222. doi:10.1080 /00288233.2005.9513666

Selby, M. J., & Hodder, A. P. W. (1993). *Hillslope materials and processes* (2nd ed.). Oxford, England: Oxford University Press.

Selby, M. J., & Hosking, P. J. (1973). The erodibility of pumice soils of the North Island, New Zealand. *Journal of Hydrology (N.Z.), 12*(1), 32-56.

Shepherd, T. G. (2009). *Visual soil assessment* (2nd ed.). Palmerston North, N.Z.: Horizons Regional Council.

Skinner, R. H. (2008). Yield, Root Growth, and Soil Water Content in Drought-Stressed Pasture Mixtures Containing Chicory. *Crop Science, 48*(1), 380-388.

Tallowin, J. R. B. (1985). Herbage losses from tiller pulling in a continuously grazed perennial ryegrass sward. *Grass and Forage Science, 40*(1), 13-18. doi:10.1111/j.1365-2494.1985.tb01715.x

Thom, E., Fraser, T., & Hume, D. (2011). Sowing methods for successful pasture establishment-a review. *Pasture Persistence Symposium. Grassland Research and Practice Series*(15), 31-37.

Thom, E. R., Burggraaf, V. T., Watts, R. J., & Hooper, R. J. (2003). Relationship of tillering and morphological characteristics of two perennial ryegrass lines to "pulling" when grazed by dairy cows. *New Zealand Journal of Agricultural Research, 46*(1), 15-25. doi:10.1080/00288233.2003.9513524

Thom, E. R., van Vught, V. T., & McCabe, R. J. (1996). Growth and persistence of perennial ryegrass lines with different tolerances to "pulling" during grazing. *Proceedings of the New Zealand Grasslands Association, 58*, 67-72.

Thom, E. R., Waugh, C. D., & McCabe, R. J. (1998). Growth and persistence of perennial and hybrid ryegrasses when grazed by dairy cows in the central Waikato region of New Zealand. *New Zealand Journal of Agricultural Research, 41*(4), 477-486.

Unger, P. W., & Kaspar, T. C. (1994). Soil Compaction and Root Growth: A Review. *Agron. J., 86*(5), 759-766. doi:10.2134/agronj1994.00021962008600050004x

Wang, J., Machado, C., Panaccione, D. G., Tsai, H.-F., & Schardl, C. L. (2004). The determinant step in ergot alkaloid biosynthesis by an endophyte of perennial ryegrass. *Fungal Genetics and Biology, 41*(2), 189-198. doi:http://dx.doi.org/10.1016/j.fgb.2003.10.002

White, J. G. H., & Hodgson, J. (1999). *New Zealand pasture and crop science*. Auckland, N.Z. ;Oxford: Oxford University Press.

Zydenbos, S., Barratt, B., Bell, N., Ferguson, C., Gerard, P., McNeill, M., . . . Jackson, T. (2011). The impact of invertebrate pests on pasture persistence and their interrelationship with biotic and abiotic factors *Pasture Persistence Symposium, Grassland Research and Practice Series* (pp. 109-117):

Zydenbos, S. M., Ferguson, C. M., Townsend, R. J., Dunbar, J. E., Peoples, S., Willoughby, B. E., . . . Jackson, T. A. (2013). Decision tools for managing insect pest outbreaks in pastures. *Proceedings of the New Zealand Grassland Association, 75*, 103-112.

Appendix 1 – Soil Profile Descriptions

Farm 9 paddock 31b

Reference data

Soil name: Series: Taupo*f*
Type: Sandy loam

Soil classification
NZ Soil Classification: Immature Orthic Pumice Soil
Soil Taxonomy: Typic Udivitrand

Site data

Location
GPS co-ordinates: 2748905 E 6307545 N
Word descriptor: Soil pit in paddock 31B, on Farm 9, located at the end of Dillon Road, (6 km down Scott Road) approx. 10 km from Mangakino

Elevation: 237 m

Geomorphic position: Profile on flat to gently indulating lowland with 000 aspect. Profile position is 50 m from toe slope of a hill.

Erosion/deposition: Negligible

Vegetation: Agricultural pasture

Drainage class: m/r

Land use: Dairy farming

Soil data

Horizon	Depth (cm)	
Ap	0-15	Dark brown (10YR 3/3) sandy loam; non-sticky; slightly plastic; peds weak and friable; moderate pedality; coarse blocky peds breaking to apedal earthy; minor very coarse blocky peds; coarse to very fine pumice fragments; moderate NaF reaction; abundant to many extremely fine roots; abrupt, wavy boundary.
Bw	15-25	Yellowish brown (10YR 5/4) sandy loam; non-sticky; slightly plastic; peds weak and friable; moderate pedality; medium blocky peds breaking to apedal earthy; medium pumice fragments; strong NaF reaction; common micro fine roots; diffuse, occluded boundary.
Cu1	25-40	Bright yellowish brown (10YR 6/6) sand; single grained, extremely fine to micro-fine grains; very friable; very weak; coarse to medium extremely fine pumice pieces; strong NaF reaction; common micro fine roots; diffuse, occluded boundary.
Cu2	40-on	Dull yellow orange (10YR 7/3) sand; single grained, extremely fine to micro-fine grains; very friable; very weak; coarse to medium extremely fine pumice pieces; moderate NaF reaction; few extremely fine roots.

Farm 9 paddock 32a

Reference data

Soil name: Series: Taupo*f*
Type: Sandy loam

Soil classification
NZ Soil Classification: Immature Orthic Pumice Soil
Soil Taxonomy: Typic Udivitrand

Site data

Location
GPS co-ordinates: 2748980 E 6307364 N
Word descriptor: Soil pit in paddock 32A, on Farm 9, located at the end of Dillon Road, (6 km down Scott Road) approx. 10 km from Mangakino
Elevation: 202 m
Geomorphic position: Profile on flat to rolling lowland with 000 aspect. Profile position is 50 m from toe slope of a hill.
Erosion/deposition: Negligible
Vegetation: Agricultural pasture
Drainage class: m/r
Land use: Dairy farming

Soil data

Horizon	Depth (cm)	
Ap	0-20	Dark brown (10YR 3/3) sandy loam; slightly sticky; slightly plastic; peds weak and friable; moderate pedality; coarse blocky peds breaking to apedal earthy; minor fine pumice; strong NaF reaction; many extremely fine roots; abrupt, wavy boundary.
Bw	20-24	Dull yellowish brown (10YR 5/4) sandy loam; non-sticky; non-plastic; peds very weak and very friable; moderate pedality; medium polyhedral peds breaking to apedal earthy; strong NaF reaction; common micro fine roots; diffuse, occluded boundary.
Cu1	24-40	Dull yellow orange (10YR 6/4) sand; single grained; grains predominantly microfine in size, minor extremely fine grains; minor medium platy peds; non-plastic; non-sticky; very weak and very friable; strong NaF reaction; common micro fine roots; abrupt, wavy boundary.
Cu2	40-on	Bright yellowish brown (10YR 7/6) pumice layer; single grained; grains medium to microfine in size; strong NaF reaction; common micro fine roots.

Farm 9 paddock 33

Reference data

Soil name: Series: Taupo*f*
Type: Sandy loam

Soil classification
NZ Soil Classification: Immature Orthic Pumice Soil
Soil Taxonomy: Typic Udivitrand

Site data

Location
GPS co-ordinates: 2748905 E 6307346 N
Word descriptor: Soil pit in paddock 33, on Farm 9, located at the end of Dillon Road, (6 km down Scott Road) approx. 10 km from Mangakino
Elevation: 230 m
Geomorphic position: Profile on flat to rolling upland with 000 aspect. Profile position is 30 m from toe slope of a hill.
Erosion/deposition: Negligible
Vegetation: Agricultural pasture
Drainage class: m/r
Land use: Dairy farming

Soil data

Horizon	Depth (cm)	
Ap	0-15	Dark brown (10YR 3/3) sandy loam; slightly sticky; slightly plastic; peds weak and friable; moderate pedality; coarse blocky peds breaking to apedal earthy; minor fine pumice; strong NaF reaction; many extremely fine roots; abrupt, wavy boundary.
Bw	15-25	Dull yellowish brown (10YR 5/4) sandy loam; non-sticky; non-plastic; peds very weak and very friable; moderate pedality; medium polyhedral peds breaking to apedal earthy; strong NaF reaction; common micro fine roots; diffuse, occluded boundary.
Cu1	25-35	Dull yellow orange (10YR 6/4) sand; single grained; grains predominantly microfine in size, minor extremely fine grains; minor medium platy peds; non-plastic; non-sticky; very weak and very friable; strong NaF reaction; common micro fine roots; abrupt, wavy boundary.
Cu2	35-on	Bright yellowish brown (10YR 7/6) pumice layer; single grained; grains medium to microfine in size; strong NaF reaction; common extremely fine roots.

Farm 14 paddock 146

Reference data

Soil name: Series: Taupo*f*
Type: Sandy loam

Soil classification
NZ Soil Classification: Immature Orthic Pumice Soil
Soil Taxonomy: Typic Udivitrand

Site data

Location
GPS co-ordinates: 2745685 E 6306205 N
Word descriptor: Soil pit in paddock 146, on Farm 14, located on Ropiha Road (8 km down Scott Road), approx. 12 km from Mangakino
Elevation: 299 m
Geomorphic position: Profile on flat to rolling upland with 000 aspect. Profile position is 20 m from shoulder slope of a hill.
Erosion/deposition: Negligible
Vegetation: Agricultural pasture
Drainage class: m/r
Land use: Dairy farming

Soil data

Horizon	Depth (cm)	
Ap1	0-10	Dark brown (10YR 3/3) sandy loam; non-sticky; slightly plastic; peds weak and friable; moderate pedality; coarse polyhedral peds breaking to apedal earthy; fine to very fine pumice and lithic fragments; weak NaF reaction; abundant to many extremely fine roots; distinct, smooth boundary.
Ap2	10-15	Black (10YR 2/1) sandy loam; slightly sticky; slightly plastic; peds weak and friable; moderate pedality; abundant medium platy peds breaking to blocky, breaking to apedal earthy; minor coarse peds; minor fine to very fine pumice pieces; strong NaF reaction; common extremely fine roots; abrupt, smooth boundary.
Bw	15-28	Dull yellow orange (10YR 6/4) sandy loam; slightly sticky; slightly plastic; peds weak and friable; moderate pedality; coarse wedge and blocky peds, breaking to apedal earthy; strong NaF reaction; common, micro fine roots; distinct, smooth boundary.
Cu	28 - on	Dull yellow orange (10YR 6/4) sand; single grained; fine to extremely fine grained; moderate NaF reaction; common micro fine roots.

Farm 14 paddock 149

Reference data

Soil name: Series: Ngakura*f*
Type: Sandy loam

Soil classification
NZ Soil Classification: Typic Orthic Pumice Soil
Soil Taxonomy: Typic Udivitrand

Site data

Location
GPS co-ordinates: 2745154 E 6306368 N
Word descriptor: Soil pit in paddock 149, on Farm 14, located on Ropiha Road (8 km down Scott Road), approx. 12 km from Mangakino
Elevation: 292 m
Geomorphic position: Profile on flat to undulating land, with 000 aspect. Profile position is 20 m from shoulder slope of gully.
Erosion/deposition: Negligible
Vegetation: Agricultural pasture
Drainage class: m/r
Land use: Dairy farming

Soil data

Horizon	Depth (cm)	
Ap	0-10	Dark brown (10YR 3/3) sandy loam; non-sticky; slightly plastic; peds very weak and friable; moderate pedality; coarse, blocky peds breaking to apedal earthy; moderate NaF reaction; many extremely fine roots; abrupt, smooth boundary.
Bw	10-22	Bright yellowish brown (10YR 6/6) loamy sand; non-sticky; non-plastic; peds weak and friable; moderate pedality; coarse polyhedral peds breaking to apedal earthy; medium to extremely fine pumice pieces; very strong NaF reaction; common micro fine roots; diffuse, occluded boundary.
Cu	22-on	Dull yellow orange (10YR 7/4) sand; single grained; fine grained; medium to very fine pumice pieces; extremely fine grained lithics; very strong NaF reaction; common micro fine roots.

Farm 14 paddock 147

Reference data

Soil name: Series: Ngakura*f*
Type: Sandy loam

Soil classification
NZ Soil Classification: Typic Orthic Pumice Soil
Soil Taxonomy: Typic Udivitrand

Site data

Location
GPS co-ordinates: 2745263 E 6306424 N
Word descriptor: Soil pit in paddock 147, on Farm 14, located on Ropiha Road (8 km down Scott Road), approx. 12 km from Mangakino
Elevation: 315 m
Geomorphic position: Profile on flat to gently undulating lowland plain, with a 000 aspect. Profile is 20 m from road.
Erosion/deposition: Negligible
Vegetation: Agricultural pasture
Drainage class: m/r
Land use: Dairy farming

Soil data

Horizon	Depth (cm)	
Ap	0-22	Dull yellowish brown (10YR 4/3) sandy loam; non-sticky; slightly plastic; peds weak and friable; strong pedality; coarse platy to polyhedral peds, breaking to apedal earthy; moderate NaF reaction; abundant extremely fine roots to 10 cm then many extremely fine roots; abrupt, wavy boundary.
Bw1	22-32	Bright yellowish brown (10YR 6/6) sandy loam; non-sticky; non-plastic; peds weak and very friable; moderate pedality; coarse to fine blocky peds breaking to apedal earthy; minor medium pumice pieces; strong NaF reaction; common micro fine roots; indistinct, occluded boundary.
Bw2	32-45	Bright yellowish brown (10YR 6/6) sandy loam; non-sticky; non-plastic; peds weak and very friable; moderate pedality; minor fine blocky peds breaking to abundant apedal earthy; minor very fine pumice pieces; strong NaF reaction; common extremely fine roots; abrupt, wavy boundary.
Cu	45-on	Dull yellow orange (10YR 6/4) sand; single grained; fine to extremely fine grained; minor medium sized pumice pieces; strong NaF reaction; no roots.

Farm 14 paddock 125

Reference data

Soil name: Series: Ngakura*f*
Type: Sandy loam

Soil classification
NZ Soil Classification: Typic Orthic Pumice Soil
Soil Taxonomy: Typic Udivitrand

Site data

Location
GPS co-ordinates: 27458592E 6306220N
Word descriptor: Soil pit in paddock 125, on Farm 14, located on Ropiha Road (8 km down Scott Road), approx. 12 km from Mangakino
Elevation: 291 m
Geomorphic position: Profile on rolling land, with 000 aspect. Profile position is approximately 15 m from road.
Erosion/deposition: Negligible
Vegetation: Agricultural pasture
Drainage class: m/r
Land use: Dairy farming

Soil data

Horizon	Depth (cm)	
Ap	0-15	Dark Brown (10YR 3/3) sandy loam; non-sticky; slightly plastic; peds weak and friable; moderate pedality; very coarse to medium polyhedral peds breaking to apedal earthy; strong NaF reaction; abundant extremely fine roots; distinct, wavy boundary.
Bw1	15-25	Bright yellowish brown (10YR 6/6) sandy loam; non-sticky; non-plastic; peds very weak and very friable; medium blocky peds breaking to apedal earthy; moderate pedality; very strong NaF reaction; common micro fine roots; diffuse, occluded boundary.
Bw2	25-40	Dull yellow orange (10YR 7/4) sandy loam; non-sticky; slightly plastic; peds weak and very friable; medium platy peds breaking to apedal earthy; strong NaF reaction; common micro fine roots; distinct, wavy boundary.
Cu	40-on	Dull yellow orange (10YR 6/4) sand; single grained; very fine to microfine grained; fine pumice pieces; strong NaF reaction; common microfine roots.

Farm 14 paddock 148

Reference data

Soil name: Series: Ngakura*f*
Type: Sandy loam

Soil classification
NZ Soil Classification: Typic Orthic Pumice Soil
Soil Taxonomy: Typic Udivitrand

Site data

Location
GPS co-ordinates: 2745419 E 6306204 N
Word descriptor: Soil pit in paddock 148, on Farm 14, located on Ropiha Road (8 km down Scott Road), approx. 12 km from Mangakino

Elevation: 295 m

Geomorphic position: Profile on flat to gently undulating lowland with 000 aspect. Profile position is 20 m from shoulder slope of a hill.

Erosion/deposition: Negligible

Vegetation: Agricultural pasture

Drainage class: m/r

Land use: Dairy farming

Soil data

Horizon	Depth (cm)	
Ap	0-10	Very dark brown (7.5YR 2/3) sandy loam; non-sticky; non-plastic; peds weak and friable; moderate pedality; medium to coarse blocky peds breaking to apedal earthy; strong NaF reaction; abundant to many extremely fine roots; indistinct, occluded boundary.
Bw1	10-20	Bright yellowish brown (10YR 7/6) sandy loam; non-sticky; slightly plastic; peds weak and friable; moderate pedality; non-sensitive; coarse to medium blocky peds breaking to apedal earthy; strong NaF reaction; common microfine roots; diffuse, occluded boundary.
Bw2	20-35	Dull yellow orange (10YR 6/4) loamy sand; non-sticky; non-plastic; peds slightly firm and friable; coarse to medium blocky peds breaking to apedal earthy; moderate NaF reaction; few microfine roots; diffuse, occluded boundary.
Cu	35-on	Dull yellow brown (10YR 7/2) sand; non-sticky; non-plastic; non-sensitive; medium gravel with medium to fine sand; apedal earthy; single grained; medium to coarse pumice pieces; weak NaF reaction; few microfine roots.

Farm 11 paddock B12

Reference data

Soil name: Series: Ngakura*f*
Type: Sandy loam

Soil classification
NZ Soil Classification: Typic Orthic Pumice Soil
Soil Taxonomy: Typic Udivitrand

Site data

Location
GPS co-ordinates: 2749752 E 6309392 N
Word descriptor: Soil pit in paddock B12, on Farm 11, located on Mitchell road, (3 km down Scott Road) approx. 12 km from Mangakino

Elevation: 285 m

Geomorphic position: Profile on upland plain of rolling land, with 000 aspect. Profile position is 15 m from shoulder slope of hill.

Erosion/deposition: Negligible

Vegetation: Agricultural pasture

Drainage class: m/r

Land use: Dairy farming

Soil data

Horizon	Depth (cm)	
Ap	0-12	Black (10YR 2/1) sandy loam; slightly plastic; slightly sticky; moderate pedality; peds weak and friable; coarse to very fine blocky peds breaking to apedal earthy; fine pumice pieces and lithics; moderate NaF reaction; abundant to many extremely fine roots; indistinct, wavy boundary.
Bw	12-20	Dull yellow orange (10YR 6/4) sandy loam; non-sticky; non-plastic; moderate pedality; peds weak and friable; medium gravel, moderately gravelly; coarse to medium blocky peds breaking to apedal earthy; very strong NaF reaction; many extremely fine roots; distinct, smooth boundary.
Cu1	20-30	Dull yellow orange (10YR 6/4) sand; single grained; moderately gravelly; medium to fine gravel pieces; abundant medium to coarse lithics; many coarse pumice pieces; strong NaF reaction; many microfine roots; distinct, wavy boundary.
Cu2	30-on	Light yellow (2.5YR 7/3) sand; single grained; moderately gravelly; medium to fine sand; abundant medium to fine lithics; many fine pumice pieces; strong NaF reaction; common microfine roots.

Farm 11 paddock A16

Reference data

Soil name: Series: Ngakura*f*
Type: Sandy loam

Soil classification
NZ Soil Classification: Typic Orthic Pumice Soil
Soil Taxonomy: Typic Udivitrand

Site data

Location
GPS co-ordinates: 2749444 E 6309628 N
Word descriptor: Soil pit in paddock A16, on Farm 11, located on Mitchell road, (3 km down Scott Road) approx. 12 km from Mangakino
Elevation: 288 m
Geomorphic position: Profile on plateau upland on rolling land, with a 000 aspect. Profile position is 15 m from shoulder slope of gully.
Erosion/deposition: Negligible
Vegetation: Agricultural pasture
Drainage class: m/r
Land use: Dairy farming

Soil data

Horizon	Depth (cm)	
Ap	0-10	Brown (7.5YR 4/3) sandy loam; non-sticky; non-plastic; moderate pedality; peds slightly firm and friable; coarse blocky peds breaking to apedal earthy; fine pumice pieces and lithics; moderate NaF reaction; many extremely fine roots; abrupt, smooth boundary.
AB	10-20	Dull brown (7.5YR 5/4) sandy loam; non-sticky; non-plastic; moderate pedality; peds slightly firm and friable; coarse blocky peds breaking to apedal earthy; fine pumice pieces and lithics; moderate NaF reaction; many extremely fine roots; abrupt, smooth boundary.
Bw	20-30	Dull orange (7.5YR 7/4) sandy loam; non-sticky; non-plastic; weak pedality; peds very weak and very friable; few medium to fine blocky peds, predominantly apedal earthy; very strong NaF reaction; common microfine roots; distinct, wavy boundary.
Cu1	30-on	Dull yellow orange (10YR 6/4) sand; single grained; fine to microfine grained; fine to microfine lithic and pumice pieces; very strong NaF reaction; common microfine roots; diffuse, occluded boundary.

Farm 15 paddock 8

Reference data

Soil name: Series: Ngakura*f*
Type: Sandy loam

Soil classification
NZ Soil Classification: Typic Orthic Pumice Soil
Soil Taxonomy: Typic Udivitrand

Site data

Location
GPS co-ordinates: 2747071 E 6305204 N
Word descriptor: Soil pit in paddock 8, on Farm 15, located at the end of Ropiha Road (8 km down Scott Road), approx. 12 km from Mangakino
Elevation: 281 m
Geomorphic position: Profile on plain in depression amongst rolling land, with 000 aspect. Profile position is 10 m from toe slopes on east and west of hills
Erosion/deposition: Negligible
Vegetation: Agricultural pasture
Drainage class: m/r
Land use: Dairy farming

Soil data

Horizon	Depth (cm)	
Ap	0-10	Black (7.5YR 2/1) sandy loam; slightly sticky; slightly plastic;brittle; slightly firm; moderate pedality; platy, coarse, breaking to strongly developed medium and coarse blocky peds to apedal earthy; abundant to many extremely fine roots; distinct, wavy boundary.
Bw1	10-20	Brown (7.5YR 4/4) sandy loam; slightly sticky; slightly plastic; weak and brittle; blocky very coarse to medium strongly developed peds breaking to apedal earthy; common microfine roots; wavy, distinct boundary.
bAh	20-28	Black (7.5YR 1.7/1) silt loam; slightly sticky; slightly plastic; wedge-like, blocky strongly developed peds breaking to angular and coarse peds; minor apedal earthy peds; few microfine roots; abrupt, smooth boundary.
bBw2	28-53	Brown (7.5YR 4/4) sandy loam; slightly sticky; slightly plastic;brittle and weak peds; blocky, extremely coarse peds breaking to medium to fine coarse blocks, breaking to apedal earthy; minor pumice and charcoal fragments; few microfine roots; smooth, abrupt boundary.
Cu	53-on	Dull yellow orange (10YR 6/4) sand; brittle and weak; apedal single grained, medium to fine sand; minor gravel obsidian; few microfine roots.

Farm 15 paddock 17

Reference data

Soil name: Series: Ngakura*f*
Type: Sandy loam

Soil classification
NZ Soil Classification: Typic Orthic Pumice Soil
Soil Taxonomy: Typic Udivitrand

Site data

Location
GPS co-ordinates: 2747686 E 6305165 N
Word descriptor: Soil pit in paddock 17, on Farm 15, located at the end of Ropiha Road (8 km down Scott Road), approx. 12 km from Mangakino
Elevation: 289 m
Geomorphic position: Profile on plateau of flat to rolling land, with a 000 aspect. Profile position is 30 m from toeslope to hill.
Erosion/deposition: Negligible
Vegetation: Agricultural pasture
Drainage class: m/r
Land use: Dairy farming

Soil data

Horizon	Depth (cm)	
Ap	0-12	Brown (7.5 4/3) gritty silt loam; slightly sticky; slightly plastic; peds brittle and weak; moderate pedality; coarse to medium polyhedral and cloddy peds breaking to apedal earthy; platy breaking of horizon at boundary layer; very weak NaF reaction; many extremely fine roots; distinct, wavy horizon.
Bw	12-18	Yellowish brown (10YR 5/6) sandy loam; slightly sticky; non-plastic; peds weak and friable; moderate pedality; coarse blocky peds breaking to apedal earthy; moderate fine gravel; strong NaF reaction; common micro fine roots; abrupt, wavy boundary.
bAh	18-23	Brownish black (7.5YR 2/2) gritty silt loam; slightly sticky; slightly plastic; non-sensitive; weak and friable peds; moderate pedality; coarse to medium platy peds breaking to apedal earthy; moderate NaF reaction; common micro fine roots; abrupt, smooth boundary.
bBw2	23-35	Yellowish brown (10YR 5/6) sandy loam; slightly sticky; slightly plastic; brittle and weak peds; moderate pedality; coarse to medium blocky peds breaking to apedal earthy; fine to very fine pumice fragments; moderate NaF reaction; common few roots; diffuse, occluded boundary.
Cu	35-on	Dull yellow orange (10YR 7/4) sand; non-sticky; non-plastic; peds very weak and very friable; very weak pedality; medium to very fine lentiform peds breaking to apedal earthy; strong NaF reaction; few microfine roots.

Farm 15 paddock 37

Reference data

Soil name: Series: Ngakura*f*
Type: Sandy loam

Soil classification
NZ Soil Classification: Typic Orthic Pumice Soil
Soil Taxonomy: Typic Udivitrand

Site data

Location
GPS co-ordinates: 2745139 E 6303316 N
Word descriptor: Soil pit in paddock 37, on Farm 15, located at the end of Ropiha Road (8 km down Scott Road), approx. 12 km from Mangakino
Elevation: 320 m
Geomorphic position: Profile on rolling land, with a 000 aspect. Profile position on terrace, 10 m from Shoulder slope of small gully.
Erosion/deposition: Negligible
Vegetation: Agricultural pasture
Drainage class: m/r
Land use: Dairy farming

Soil data

Horizon	Depth (cm)	
Ap	0-14	Brownish black (10YR 3/2) sandy loam; non-sticky; slightly plastic; peds slightly firm and brittle; non-sensitive; peds breaking platy at 5 cm depth; coarse to fine blocky peds breaking to apedal earthy; strong NaF reaction; worms present; many extremely fine roots; abrupt, wavy boundary.
Bw	14-35	Yellowish brown (10YR 5/6) sandy loam; non-sticky; non-plastic; non-sensitive; peds weak and friable; coarse to medium polyhedral peds breaking to apedal earthy; minor medium spheroidal pumice pieces; strong NaF reaction; worms present; common extremely fine roots; diffuse, occluded boundary.
Cu	35-on	Dull yellow orange (10YR 6/4) sand; single grained; very fine to extremely fine grained; very fine to fine pumice and lithic fragments; very strong NaF reaction; common microfine roots.

Farm 15 paddock 15

Reference data

Soil name: Series: Ngakura*f*
Type: Sandy loam

Soil classification
NZ Soil Classification: Typic Orthic Pumice Soil
Soil Taxonomy: Typic Udivitrand

Site data

Location
GPS co-ordinates: 2747787 E 6305280 N
Word descriptor: Soil pit in paddock 15, on Farm 15, located at the end of Ropiha Road (8 km down Scott Road), approx. 12 km from Mangakino
Elevation: 295 m
Geomorphic position: Profile on plateau of undulating to easy rolling land, with a 000 aspect. Profile position is in small depression of plateau.
Erosion/deposition: Negligible
Vegetation: Agricultural pasture
Drainage class: m/r
Land use: Dairy farming

Soil data

Horizon	Depth (cm)	
Ap	0-10	Brownish black (7.5YR 3/2) silt loam; non-sticky; slightly plastic; non-sensitive; peds weak and very friable; moderate pedality; fine to very fine polyhedral peds breaking to apedal earthy; minor gritty fine sand; strong NaF reaction; abundant extremely fine roots; distinct occluded boundary.
bAh	10-15	Black (7.5YR 2/1) silt loam; non-sticky; non-plastic; non-sensitive; peds weak and very friable; fine to very fine polyhedral peds breaking to apedal earthy, minor fine gritty sand; moderate NaF reaction; many extremely fine roots; abrupt, wavy boundary.
Cu1	15-25	Yellow orange (10YR 8/6) sand; non-sticky; single grained; minor coarse to medium pumice pieces; moderate NaF reaction; many microfine roots; diffuse, occluded boundary.
Cu2	25-on	Dull yellow orange (10YR 7/4) sand; single grained; very fine to microfine grained; fine lithic and pumice fragments present; moderate NaF reaction; many microfine roots.

Farm 15 paddock 35

Reference data

Soil name: Series: Ngakura*f*
Type: Sandy loam

Soil classification
NZ Soil Classification: Typic Orthic Pumice Soil
Soil Taxonomy: Typic Udivitrand

Site data

Location
GPS co-ordinates: 2745250 E 6303202 N
Word descriptor: Soil pit in paddock 35, on Farm 15, located at the end of Ropiha Road (8 km down Scott Road), approx. 12 km from Mangakino
Elevation: 318 m
Geomorphic position: Profile on undulating to easy rolling lowland, with a 000 aspect. Profile position is on midslope of shallow depression.
Erosion/deposition: Negligible
Vegetation: Agricultural pasture
Drainage class: m/r
Land use: Dairy stock grazing

Soil data

Horizon	Depth (cm)	
Ap	0-10	Brownish black (10YR 3/2) sandy loam; non-sticky; slightly plastic; peds slightly firm and brittle; non-sensitive; peds breaking platy at 5 cm depth; coarse to fine blocky peds breaking to apedal earthy; strong NaF reaction; worms present; many extremely fine roots that break off at horizon boundary; distinct, wavy boundary.
Bw	10-25	Yellowish brown (10YR 5/6) sandy loam; non-sticky; non-plastic; non-sensitive; peds weak and friable; coarse to medium polyhedral peds breaking to apedal earthy; minor medium spheroidal pumice pieces; strong NaF reaction; worms present; common extremely fine roots; diffuse, occluded boundary.
Cu	25-on	Dull yellow orange (10YR 6/4) sand; single grained; very fine to extremely fine grained; course to medium pumice fragments; very strong NaF reaction; few microfine roots.

Soil pit GPS co-ordinates

Farm	Paddock	Season	Easting	Northing	Elevation
15	8	summer	2747071	6305204	281
14	148	summer	2745419	6306204	295
15	15	summer	2747787	6305280	295
15	17	summer	2747686	6305165	289
15	37	summer	2745139	6303316	320
15	35	summer	2745250	6303202	318
11	B12	summer	2749752	6309392	285
14	146	summer	2745685	6306205	299
14	149	summer	2745154	6306368	292
14	147	summer	2745263	6306424	315
14	125	summer	2745859	6306220	291
11	A16	summer	2749444	6309628	288
9	31B	summer	2749011	6307545	237
9	32A	summer	2748980	6307364	202
9	33	summer	2748905	6307346	230
15	15	autumn	2747785	6305280	290
15	17	autumn	2747683	6305164	289
15	8	autumn	2747071	6305207	277
15	35	autumn	2745246	6303202	333
15	37	autumn	2745137	6303321	322
11	A16	autumn	2749445	6309631	289
14	149	autumn	2745154	6306375	306
14	147	autumn	2745257	6306426	309
14	146	summer	2745693	6306235	298
14	146	autumn	2745691	6306237	298
14	148	autumn	2745421	6306206	302
14	125	autumn	2745861	6306222	286
9	31B	autumn	2749011	6307552	237
9	32A	autumn	2748982	6307368	232
9	33	autumn	2748895	6307351	232
11	B12	autumn	2749757	6309403	279
15	15	winter	2747788	6305281	287
15	17	winter	2747690	6305163	288
15	8	winter	2747075	6305204	280
15	35	winter	2745253	6303201	327
11	A16	winter	2749449	6309626	289
11	B12	winter	2749753	6309626	283
14	147	winter	2745267	6306422	304
14	149	winter	2745156	6306364	307
14	146	winter	2745699	6306232	300
14	148	winter	2745424	6306198	301
14	125	winter	2745863	6306219	290
9	31B	winter	2749018	6307547	235

Farm	Paddock	Season	Easting	Northing	Elevation
9	32A	winter	2748984	6307363	234
15	37	winter	2745140	6303319	323
9	33	winter	2748909	6307345	236
15	15	spring	2747786	6305276	292
15	17	spring	2747684	6305158	293
15	8	spring	2747073	6305198	281
15	35	spring	2745249	6303199	326
15	37	spring	2745143	6303331	320
11	A16	spring	2749442	6309620	292
11	B12	spring	2749750	6309388	287
14	147	spring	2745263	6306420	295
14	149	spring	2745151	6306363	308
14	146	spring	2745692	6306233	297
14	148	spring	2745417	6306200	304
14	125	spring	2745857	6306213	295
9	31B	spring	2749014	6307545	242
9	32A	spring	2748980	6307362	232
9	33	spring	2748903	6307341	232

Appendix 2 – Soil pH

Sample number	Date sampled	Farm	Paddock	Horizon	Depth (cm)	pH
1	13/01/2014	15	8	Ap	0-5	5.88
2	13/01/2014	15	8	Ap	5-10	6.12
3	13/01/2014	15	8	Bw1	10-20	5.37
4	13/01/2014	15	8	bAh	20-28	5.22
5	13/01/2014	15	8	bBw 2	28-53	5.51
6	13/01/2014	15	8	Cu	53-70	5.83
7	21/01/2014	15	15	Ap	0-5	5.92
8	21/01/2014	15	15	Ap	5-10	5.85
9	21/01/2014	15	15	Bw	10-15	5.75
10	21/01/2014	15	15	Cu1	15-25	5.65
11	21/01/2014	15	15	Cu2	25 on	5.78
12	22/01/2014	11	B12	Ap	0-5	6.05
13	22/01/2014	11	B12	Ap	5-10	5.75
14	22/01/2014	11	B12	Bw	12-20	5.58
15	22/01/2014	11	B12	Cu1	20-30	5.69
16	22/01/2014	11	B12	Cu2	30 on	5.81
17	22/01/2014	15	37	Ap	0-5	6.28
18	22/01/2014	15	37	Ap	5-10	5.64
19	22/01/2014	15	37	Bw	14-35	5.76
20	22/01/2014	15	37	Cu	35 on	5.66
21	22/01/2014	15	35	Ap	0-5	6.21
22	22/01/2014	15	35	Ap	5-10	6.09
23	22/01/2014	15	35	Bw	10-25	6.21
24	22/01/2014	15	35	Cu	25 on	6.30
25	23/01/2014	14	147	Ap	0-5	5.38
26	23/01/2014	14	147	Ap	5-10	5.41
27	23/01/2014	14	147	Bw1	22-32	5.23
28	23/01/2014	14	147	Bw2	32-45	5.37
29	23/01/2014	14	147	Cu	45-on	5.57
30	23/01/2014	14	149	Ap	0-5	5.57
31	23/01/2014	14	149	Ap	5-10	5.32
32	23/01/2014	14	149	Bw	10-22	5.52
33	23/01/2014	14	149	Cu	22- on	5.77
34	22/01/2014	14	146	Ap1	0-5	5.49
35	22/01/2014	14	146	Ap1	5-10	5.73
36	22/01/2014	14	146	Ap2	10-15	5.73
37	22/01/2014	14	146	Bw	15-28	5.70
38	22/01/2014	14	146	Cu	28-on	5.87
39	23/01/2014	14	148	Ap	0-5	5.68
40	23/01/2014	14	148	Ap	5-10	5.49
41	23/01/2014	14	148	Bw1	10-20	5.54
42	23/01/2014	14	148	Bw2	20-35	6.07
43	23/01/2014	14	148	Cu	35-on	6.14
44	23/01/2014	14	125	Ap	0-5	6.16
45	23/01/2014	14	125	Ap	5-10	5.87
46	23/01/2014	14	125	Bw1	15-25	5.67
47	23/01/2014	14	125	Bw2	25-40	5.84
48	23/01/2014	14	125	Cu	40-on	6.15
49	23/01/2014	11	A16	Ap	0-5	5.89
50	23/01/2014	11	A16	Ap	5-10	5.80
51	23/01/2014	11	A16	Bw	20-30	5.53
52	23/01/2014	11	A16	Cu1	30-45	5.58
53	22/01/2014	15	17	Ap	0-5	6.60
54	22/01/2014	15	17	Ap	5-10	6.28

Sample number	Date sampled	Farm	Paddock	Horizon	Depth (cm)	pH
55	22/01/2014	15	17	Bw	12-18	6.12
56	22/01/2014	15	17	bAh	18-23	5.70
57	22/01/2014	15	17	bBw	23-25	5.60
58	22/01/2014	15	17	Cu	35-on	5.84
59	24/01/2014	9	31B	Ap	0-5	5.52
60	24/01/2014	9	31B	Ap	5-10	5.50
61	24/01/2014	9	31B	Bw1	15-25	5.42
62	24/01/2014	9	31B	Cu1	25-40	5.70
63	24/01/2014	9	31B	Cu2	40-on	5.99
64	24/01/2014	9	33	Ap	0-5	6.28
65	24/01/2014	9	33	Ap	5-10	6.24
66	24/01/2014	9	33	Bw	15-25	6.07
67	24/01/2014	9	33	Cu1	25-35	5.88
68	24/01/2014	9	33	Cu2	35-on	5.80
69	24/01/2014	9	32A	Ap	0-5	5.51
70	24/01/2014	9	32A	Ap	5-10	5.24
71	24/01/2014	9	32A	Bw	20-24	5.34
72	24/01/2014	9	32A	Cu1	24-40	5.62
73	24/01/2014	9	32A	Cu2	40-on	6.45

Appendix 3- Pasture Pulling Data

20th January 2014

Paddock conditions

Farm	*Paddock*	*Conditions*
15	8	More than 3 weeks since grazing. Not as established, still see rows where has been sown. Patchy and clumpy.
15	15	Good condition, several weeks since grazing, clover flowering. Pulling by cows is evident.
15	17	Good pasture, several weeks since grazing. Lots of clover flowering.
9	33	Has not been grazed recently. Wild pigs have pulled out large patches of pasture. Established, old pasture.
15	35	Grazed in last 3 weeks, overall good condition.
15	37	Not grazed in at least 6 weeks. Pasture long and lush.
14	125	Good condition, established pasture, a lot of grass cover, at least a month since grazing.
14	146	Has not been grazed for a while. Established pasture, good pasture coverage. Some bare ground etc.
14	147	Hasn't been grazed in a while, looks to be ready to graze soon. Good condition, not patchy, not a lot of bare ground.
14	148	Hasn't been grazed recently. Thick sward, lots of different species
14	149	Large high post on right from gate in middle of paddock. Very diverse pasture, established, not a lot of bare ground
9	31B	Hasn't been grazed in a while. Long, lush pasture. Ryegrass + clover.
9	32A	Been grazed in last 3 weeks. A bit patchy on knolls of hills.
11	A16	Chicory still present. Grazed recently in last 3 weeks. Still see sowing lines. Lots of clover.
11	B12	Grazed in last couple of weeks, well developed pasture.

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
15	8	1	1	0	0	1	1	30	0	5	10	50	5
15	8	2	8	0	0	8	8	50	0	0	20	30	0
15	8	3	1	1	0	2	4	60	0	0	10	30	0
15	8	4	1	0	0	1	1	25	0	5	25	40	5
15	8	5	8	0	0	8	8	60	0	0	20	20	0
15	15	1	2	0	0	2	2	33	33	1	33	0	0
15	15	2	1	1	0	2	4	15	50	10	15	10	0

15	15	3	1	0	0	1	1	5	40	20	30	5	0
Farm	***Paddock***	***Quadrat***	***Small Pulls***	***Medium Pulls***	***Large Pulls***	***Pulling Total***	***Pulling Index***	***Ryegrass***	***Browntop***	***Weeds***	***Clover***	***Bare Ground***	***Other***
15	15	4	4	2	0	6	10	30	40	5	15	10	0
15	15	5	4	0	0	4	4	50	30	5	10	5	0
15	17	1	0	0	0	0	0	30	0	0	60	10	0
15	17	2	0	2	0	2	6	45	0	0	45	10	0
15	17	3	3	0	0	3	3	45	0	0	45	10	0
15	17	4	0	0	0	0	0	45	0	0	45	10	0
15	17	5	0	0	0	0	0	20	0	0	75	5	0
9	33	1	0	0	0	0	0	0	70	5	25	0	0
9	33	2	1	0	0	1	1	0	65	10	5	5	10
9	33	3	0	0	0	0	0	0	30	50	10	0	10
9	33	4	0	0	0	0	0	20	40	5	30	5	0
9	33	5	0	0	0	0	0	0	40	20	5	0	0
15	35	1	2	0	0	2	2	45	0	0	5	50	0
15	35	2	1	0	0	1	1	50	0	0	0	50	0
15	35	3	1	0	0	1	1	50	0	0	5	45	0
15	35	4	5	0	0	5	5	70	0	0	0	30	0
15	35	5	0	0	0	0	0	50	0	0	0	50	0
15	37	1	0	0	0	0	0	80	0	0	0	20	0
15	37	2	0	0	0	0	0	80	0	0	0	20	0
15	37	3	0	0	0	0	0	90	0	0	0	10	0
15	37	4	0	0	0	0	0	80	0	0	10	10	0
15	37	5	1	0	0	1	1	60	0	5	30	5	0
14	125	1	1	0	0	1	1	50	15	5	25	5	0
14	125	2	0	0	0	0	0	10	75	10	0	5	0
14	125	3	1	0	0	1	1	20	70	5	0	5	0
14	125	4	0	0	0	0	0	15	75	5	5	0	0
14	125	5	0	0	0	0	0	10	60	25	0	5	0
14	146	1	1	0	0	1	1	20	50	5	0	25	0
14	146	2	0	0	0	0	0	10	70	0	0	20	0
14	146	3	1	0	0	1	1	30	60	0	0	10	0
14	146	4	1	0	0	1	1	55	30	0	0	15	0
14	146	5	1	0	0	1	1	40	40	0	0	20	0
14	147	1	4	3	0	7	13	70	15	0	5	10	0
14	147	2	3	0	0	3	3	80	0	0	10	10	0

14	147	3	12	1	0	13	15	50	0	0	10	40	0
Farm	***Paddock***	***Quadrat***	***Small Pulls***	***Medium Pulls***	***Large Pulls***	***Pulling Total***	***Pulling Index***	***Ryegrass***	***Browntop***	***Weeds***	***Clover***	***Bare Ground***	***Other***
14	147	4	10	0	0	10	10	55	0	0	5	40	0
14	147	5	4	1	0	5	7	50	0	0	15	35	0
14	148	1	0	0	0	0	0	15	80	0	0	5	0
14	148	2	0	0	0	0	0	30	50	5	15	0	0
14	148	3	0	0	0	0	0	55	45	0	5	0	0
14	148	4	0	0	0	0	0	15	60	0	5	20	0
14	148	5	0	0	0	0	0	25	30	0	15	0	30
14	149	1	0	1	0	1	3	20	20	10	30	0	20
14	149	2	2	0	0	2	2	20	30	30	20	0	0
14	149	3	0	1	0	1	3	20	20	0	20	10	20
14	149	4	10	1	0	11	13	30	20	5	20	5	20
14	149	5	3	0	0	3	3	30	20	20	30	0	0
9	31B	1	3	0	0	3	3	70	0	0	25	5	0
9	31B	2	1	0	0	1	1	80	0	0	15	5	0
9	31B	3	0	0	0	0	0	65	0	0	30	5	0
9	31B	4	0	0	0	0	0	70	0	0	20	10	0
9	31B	5	1	0	0	1	1	90	0	0	5	5	0
9	32A	1	8	3	0	11	17	55	0	0	40	5	0
9	32A	2	1	2	0	3	7	45	0	10	25	20	0
9	32A	3	0	0	0	0	0	60	0	5	10	25	0
9	32A	4	4	0	0	4	4	70	0	0	5	25	0
9	32A	5	0	4	8	12	52	70	0	0	0	30	0
11	A16	1	5	1	0	6	8	50	0	0	30	20	5
11	A16	2	9	5	0	14	24	35	0	0	20	40	5
11	A16	3	4	0	0	4	4	30	10	0	30	25	5
11	A16	4	6	0	0	6	6	40	0	0	50	10	0
11	A16	5	6	0	0	6	6	40	10	0	35	10	5
11	B12	1	0	0	0	0	0	20	0	0	20	5	55
11	B12	2	1	0	0	1	1	20	0	20	10	0	50
11	B12	3	5	0	0	5	5	0	0	0	5	10	45
11	B12	4	3	0	0	3	3	10	0	5	10	5	0
11	B12	5	2	1	0	3	5	0	50	20	10	0	20

12th February 2014

Paddock conditions

Farm	*Paddock*	*Conditions*
15	8	Has not been grazed recently, pasture long and lush.
15	15	Recently grazed, in last the 2 weeks. Grass dying off.
15	17	Grazed in last couple of days, pasture short, a few pulls around.
9	33	Has not been grazed recently, pasture is quite long and in good condition.
15	35	Grazed in the last week, pasture short, a few fresh pulls in paddock.
15	37	Good pasture condition, grazed in last 2 weeks.
14	125	Has not been grazed in last few weeks, pasture long and lush.
14	146	Probably 3 weeks since last grazing, pasture long and due to be grazed.
14	147	Hasn't been grazed in at least 3 weeks. Dry, lots of long grass.
14	148	Recently grazed, few small pulls around.
14	149	Grazed in last few weeks, pasture getting longer again, fairly good condition.
9	31B	Has not been grazed recently, pasture long.
9	32A	Grazed in last couple of weeks. Pasture condition OK, only a few pulls around.
11	A16	Grazed in last couple of weeks. Quite patchy, odd chicory plant in paddock. A few pulls about.
11	B12	Has not been grazed in over 3 weeks, pasture quite long.

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
15	8	1	0	3	0	3	9	60	0	0	10	30	0
15	8	2	0	0	0	0	0	65	0	0	10	25	0
15	8	3	3	2	0	5	9	40	0	5	5	50	0
15	8	4	2	1	0	3	5	30	0	0	10	55	5
15	8	5	8	0	0	8	8	65	0	0	10	25	0
15	15	1	9	1	0	10	12	20	10	10	30	20	10
15	15	2	19	1	0	20	22	20	20	15	25	20	0
15	15	3	8	3	1	12	22	35	0	0	15	50	0
15	15	4	3	0	0	3	3	10	65	0	15	10	0
15	15	5	9	0	0	9	9	15	40	10	20	15	0
15	17	1	5	0	0	5	5	30	0	0	30	40	0
15	17	2	4	2	0	6	10	50	0	0	20	30	0

Farm	Paddock	Quadrat	Small Pulls	Medium Pulls	Large Pulls	Pulling Total	Pulling Index	Ryegrass	Browntop	Weeds	Clover	Bare Ground	Other
15	17	3	3	0	0	3	3	35	0	0	25	40	0
15	17	4	3	1	0	4	6	50	0	0	35	15	0
15	17	5	4	0	0	4	4	50	0	0	30	20	0
9	33	1	2	0	0	2	2	20	40	0	5	5	30
9	33	2	6	0	0	6	6	30	20	5	20	15	15
9	33	3	1	0	0	1	1	40	20	5	25	5	5
9	33	4	1	0	0	1	1	20	40	15	5	15	5
9	33	5	0	0	0	0	0	30	15	30	5	5	15
15	35	1	10	0	0	10	10	75	0	0	0	25	0
15	35	2	4	0	1	5	9	55	0	0	0	40	0
15	35	3	2	1	0	3	5	65	0	5	0	30	0
15	35	4	4	0	0	4	4	65	0	0	5	30	0
15	35	5	3	0	0	3	3	70	0	0	5	30	0
15	37	1	2	1	1	4	10	50	0	20	5	25	0
15	37	2	2	1	0	3	5	45	0	10	5	40	0
15	37	3	2	2	0	4	8	60	0	0	10	30	0
15	37	4	5	5	2	12	30	70	0	0	10	20	0
15	37	5	4	2	0	6	10	60	0	5	15	20	0
14	125	1	4	1	0	5	7	50	10	15	20	5	0
14	125	2	2	0	0	2	2	50	35	10	0	5	0
14	125	3	2	0	0	2	2	60	30	10	0	0	0
14	125	4	1	0	0	1	1	30	45	20	5	0	0
14	125	5	0	2	0	2	6	40	40	5	0	15	0
14	146	1	1	0	0	1	1	40	30	0	0	30	0
14	146	2	0	1	0	1	3	40	30	0	0	30	0
14	146	3	0	0	0	0	0	45	30	0	0	25	0
14	146	4	0	0	0	0	0	40	40	0	0	20	0
14	146	5	0	0	0	0	0	50	20	0	0	30	0
14	147	1	1	1	0	2	4	80	0	0	5	15	0
14	147	2	5	1	0	6	8	55	0	0	15	30	0
14	147	3	6	0	0	6	6	65	0	0	15	20	0
14	147	4	7	0	0	7	7	40	10	0	20	30	0
14	147	5	3	0	0	3	3	50	5	0	5	40	0
14	148	1	10	0	0	10	10	50	40	0	5	5	0
14	148	2	10	0	0	10	10	40	40	0	15	0	5

Farm	Paddock	Quadrat	Small Pulls	Medium Pulls	Large Pulls	Pulling Total	Pulling Index	Ryegrass	Browntop	Weeds	Clover	Bare Ground	Other
14	148	3	2	1	0	3	5	50	30	0	10	0	10
14	148	4	0	0	0	0	0	40	35	5	15	5	0
14	148	5	1	0	0	1	1	70	30	0	0	0	0
14	149	1	1	0	0	1	1	20	15	20	25	10	10
14	149	2	3	0	0	3	3	20	20	20	20	10	10
14	149	3	4	0	0	4	4	20	20	30	20	5	5
14	149	4	1	0	0	1	1	20	20	25	20	0	15
14	149	5	1	0	0	1	1	20	15	25	30	0	10
9	31B	1	4	0	0	4	4	60	0	0	15	25	0
9	31B	2	0	0	0	0	0	60	0	5	15	20	0
9	31B	3	4	0	0	4	4	75	0	0	15	10	0
9	31B	4	1	0	0	1	1	75	0	5	5	15	0
9	31B	5	3	0	0	3	3	80	0	0	5	15	0
9	32A	1	6	0	0	6	6	50	0	0	20	30	0
9	32A	2	5	0	0	5	5	55	0	5	5	35	0
9	32A	3	3	0	0	3	3	50	0	5	5	40	0
9	32A	4	0	1	0	1	3	50	0	5	5	40	0
9	32A	5	1	1	0	2	4	55	0	5	10	30	0
11	A16	1	7	2	0	9	13	20	0	5	10	50	15
11	A16	2	13	2	0	15	19	20	0	0	20	50	10
11	A16	3	9	2	0	11	15	35	0	0	15	35	15
11	A16	4	15	2	0	17	21	35	0	0	20	40	5
11	A16	5	5	0	0	5	5	40	0	0	10	40	10
11	B12	1	0	0	0	0	0	20	15	20	10	5	30
11	B12	2	0	0	0	0	0	20	30	30	15	0	5
11	B12	3	2	0	0	2	2	20	40	20	10	10	0
11	B12	4	4	0	0	4	4	5	20	35	20	0	30
11	B12	5	0	0	0	0	0	5	15	40	10	0	30

6th March 2014

Paddock conditions

Farm	*Paddock*	*Conditions*
15	8	2 weeks since last grazing. Dry and dead pasture.
15	15	Dry, dead pulls. A month since grazing. Not a lot growing.
15	17	A lot of clover, grass greener than other paddocks. No grazing in last 3 weeks.
9	33	Grazed last couple of days. Dead, dry and short pasture.
15	35	Dry, dead, short pasture. Grazed approx. 1 week ago.
15	37	Dry, dead short pasture. At least a month since grazing.
14	125	Dry, dead pasture. Hasn't been grazed in over a month.
14	146	Dry, dead pasture. No grazing in at least a month.
14	147	Dead, dry grass going to seed. Has not been grazed in at least a month.
14	148	Recently grazed, last few days. Slightly greener than other paddocks.
14	149	Hasn't been grazed in over a month. Mainly dry, dead pasture. Gone into seed.
9	31B	Hasn't been grazed in at least a month, dead and dry pasture.
9	32A	Dry, dead pasture. A bit greener than other paddocks. Has not been grazed in at least a month.
11	A16	Grass dead and dry, has not been grazed in weeks so was not assessed.
11	B12	Paddock has not been grazed in over a month and grass is too long to see any pulling so was not assessed.

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
15	8	1	3	0	0	3	3	80	5	0	0	15	0
15	8	2	1	0	0	1	1	90	0	0	0	10	0
15	8	3	0	0	0	0	0	75	0	0	0	25	0
15	8	4	2	0	1	3	7	25	0	0	15	60	0
15	8	5	3	2	0	5	9	70	0	0	0	25	5
15	15	1	30	3	2	35	49	50	5	0	40	5	0
15	15	2	6	0	0	6	6	10	55	10	20	5	0
15	15	3	5	3	0	8	14	40	10	0	30	20	0
15	15	4	8	1	0	9	11	60	10	5	15	10	0
15	15	5	17	1	0	18	20	60	15	0	15	10	0
15	17	1	12	0	0	12	12	25	15	0	50	10	0
15	17	2	7	2	0	9	13	30	20	0	40	10	0

Farm	Paddock	Quadrat	Small Pulls	Medium Pulls	Large Pulls	Pulling Total	Pulling Index	Ryegrass	Browntop	Weeds	Clover	Bare Ground	Other
15	17	3	2	0	0	2	2	30	20	0	30	20	0
15	17	4	2	1	0	3	5	55	20	5	10	10	0
15	17	5	2	0	0	2	2	30	15	0	50	5	0
9	33	1	0	1	0	1	3	10	80	10	0	0	0
9	33	2	0	0	0	0	0	0	90	5	0	5	0
9	33	3	3	0	0	3	3	0	70	15	0	5	10
9	33	4	9	1	0	10	12	5	90	0	0	5	0
9	33	5	9	0	0	9	9	0	80	10	0	0	10
15	35	1	20	1	0	21	23	80	0	0	0	20	0
15	35	2	1	0	0	1	1	75	0	10	0	15	0
15	35	3	7	0	0	7	7	75	0	0	0	25	0
15	35	4	4	1	0	5	7	75	0	0	0	25	0
15	35	5	2	0	0	2	2	85	0	0	0	15	0
15	37	1	6	1	1	8	14	60	0	10	0	30	0
15	37	2	7	0	0	7	7	60	0	0	0	40	0
15	37	3	1	2	1	4	12	70	0	0	0	30	0
15	37	4	6	3	0	9	15	70	0	0	5	25	0
15	37	5	5	2	0	7	11	85	0	0	0	15	0
14	125	1	4	2	0	6	10	25	70	0	5	0	0
14	125	2	1	0	0	1	1	0	90	10	0	0	0
14	125	3	12	0	0	12	12	25	50	20	0	5	0
14	125	4	0	0	0	0	0	20	70	0	10	0	0
14	125	5	11	0	1	12	16	30	35	5	10	20	0
14	146	1	1	0	0	1	1	40	45	0	0	15	0
14	146	2	1	1	0	2	4	40	30	0	0	30	0
14	146	3	7	0	0	7	7	50	35	0	0	15	0
14	146	4	0	0	0	0	0	30	60	0	0	5	5
14	146	5	0	0	0	0	0	70	25	0	0	5	0
14	147	1	12	0	0	12	12	80	10	0	0	10	0
14	147	2	0	0	0	0	0	80	15	0	0	5	0
14	147	3	2	0	0	2	2	75	10	0	0	15	0
14	147	4	10	0	0	10	10	70	10	0	0	20	0
14	147	5	4	0	0	4	4	65	5	5	0	25	0
14	148	1	3	0	0	3	3	50	50	0	0	0	0
14	148	2	2	0	0	2	2	40	60	0	0	0	0

Farm	Paddock	Quadrat	Small Pulls	Medium Pulls	Large Pulls	Pulling Total	Pulling Index	Ryegrass	Browntop	Weeds	Clover	Bare Ground	Other
14	148	3	2	0	0	2	2	35	60	0	0	0	5
14	148	4	7	0	0	7	7	40	60	0	0	0	0
14	148	5	0	0	0	0	0	30	60	0	5	5	0
14	149	1	6	0	0	6	6	30	30	25	5	5	5
14	149	2	3	0	0	3	3	30	35	25	5	0	5
14	149	3	7	0	0	7	7	40	10	40	10	0	0
14	149	4	3	0	0	3	3	20	40	25	10	0	5
14	149	5	1	0	0	1	1	30	25	30	10	0	5
9	31B	1	0	0	0	0	0	60	0	0	15	20	5
9	31B	2	0	0	0	0	0	80	0	0	10	5	5
9	31B	3	0	0	0	0	0	85	0	0	10	5	0
9	31B	4	0	0	0	0	0	80	0	0	5	15	0
9	31B	5	0	0	0	0	0	90	0	5	5	0	0
9	32A	1	5	0	0	5	5	60	0	5	5	30	0
9	32A	2	6	3	0	9	15	65	0	0	5	30	0
9	32A	3	0	0	0	0	0	50	0	10	0	40	0
9	32A	4	0	0	0	0	0	75	0	0	0	25	0
9	32A	5	1	0	0	1	1	60	0	10	5	25	0

28th March 2014

Paddock conditions

Farm	Paddock	Conditions
15	8	Greener, has been recently grazed but evidence of supplementary feed, so not sure how much grass has been eaten. Grass reasonably short.
15	15	Much greener than last time, grass has grown but not significantly. A lot still dead. Pasture assessment not conducted as had not been grazed, no fresh pulls.
15	17	Has been grazed in last 3 weeks. But probably given supplementary feed because a lot of ruffage in cow pats, not much pulling visible and first glance. Grass not very long. Greener than last time, so has rained a bit.
9	33	Has not been grazed since last assessment. Greener and longer. Evidence of supplementary feed from last time.
15	35	Hasn't been grazed since last time pasture assessment was conducted. No assessment conducted today. Grass greener and longer.
15	37	Currently being grazed so could not do pasture assessment. Could see quite large pulls in paddock being formed.
14	125	Paddock greener than last time. Longer, but has not been grazed. No pasture assessment conducted.
14	146	Has not been grazed in at least 6 weeks. Long, dead pasture that has slightly greened up since last time.

14	147	No new grazing, so pasture assessment was not completed. Greener pasture, has grown a bit.
14	148	Has not been grazed in at least a month. Grass greener but has not grown much.
14	149	No grazing in weeks so no pasture assessment conducted. Grass greener and longer.
9	31B	Has been grazed since last pasture assessment. Grass greener and short. Evidence of supplementary feed.
9	32A	Has not been grazed since last assessment. Greener, longer, no evidence of supplementary feed. No pasture assessment conducted.
11	A16	No pasture assessment completed, has not been grazed in over 6 weeks. Most of the grass is dead. Chicory is growing.
11	B12	Has not been grazed in weeks. Most pasture dead or has gone to seed. No pasture assessment completed because of this.

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
15	8	1	1	1	0	2	4	60	0	0	0	40	0
15	8	2	0	0	0	0	0	75	0	0	0	25	0
15	8	3	1	0	0	1	1	40	0	0	0	60	0
15	8	4	1	0	0	1	1	70	0	0	0	30	0
15	8	5	1	0	0	1	1	40	0	0	0	60	0
15	17	1	6	0	0	6	6	35	0	0	50	15	0
15	17	2	4	7	0	11	25	45	0	0	20	35	0
15	17	3	1	2	0	3	7	40	0	0	30	30	0
15	17	4	5	4	0	9	17	30	0	0	40	20	0
15	17	5	3	1	0	4	6	35	0	0	50	15	0
9	31B	1	0	0	0	0	0	55	0	5	15	25	0
9	31B	2	1	0	0	1	1	60	0	0	0	40	0
9	31B	3	0	0	0	0	0	75	0	0	5	20	0
9	31B	4	4	0	0	4	4	40	0	0	0	60	0
9	31B	5	2	0	0	2	2	30	0	0	0	70	0

24th April 2014

Paddock conditions

Farm	*Paddock*	*Conditions*
15	8	Very patchy, a lot of bare ground. Grass very clumpy where drill lines are. Chicory growing.
15	15	Grass long and green. Has been grazed since soil sampled.
15	17	Paddock has been sprayed off and under sown into new grass.
9	33	Hasn't been grazed since last assessment so no pasture assessment completed.
15	35	No pasture assessment conducted. Has not been grazed, grass long and lush.
15	37	Long, lush green pasture. No assessment because has not been grazed since last assessment, and grass is too long to see pulling.
14	125	Recently grazed, good pasture. Green and lush, grazed quite short.
14	146	Grazed recently. Good pasture, green and lush.
14	147	Grazed recently. Green grass, not very short.
14	148	Grazed recently. Thick green grass. Good condition.
14	149	Recently grazed. Pasture condition good, diverse species.
9	31B	Has not been grazed since last assessment. Grass longer and much greener, very lush.
9	32A	Grazing was in process so pasture assessment could not be conducted.
11	A16	Must have been grazed just after last assessment. Pasture very clumpy, reasonable length. Chicory grown lots. Large amount of bare ground.
11	B12	Grazed in last couple of weeks. Pasture quite green and lush. Bare patches also. A lot of pulling seen outside quadrants.

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
15	8	1	4	0	0	4	4	75	0	0	0	25	0
15	8	2	2	0	0	2	2	60	0	5	0	35	10
15	8	3	2	0	0	2	2	75	0	0	5	20	0
15	8	4	0	0	0	0	0	60	0	0	0	40	0
15	8	5	8	6	0	14	26	30	0	20	0	50	0
15	15	1	6	0	0	6	6	70	0	10	10	10	0
15	15	2	4	1	0	5	7	65	0	15	10	10	0
15	15	3	3	2	0	5	9	45	0	5	40	10	0
15	15	4	2	0	0	2	2	60	0	15	20	5	0
15	15	5	3	0	0	3	3	85	0	0	10	5	0
14	125	1	10	3	0	13	19	45	40	0	5	10	0
14	125	2	2	1	0	3	5	20	80	0	0	0	0

Farm	Paddock	Quadrat	Small Pulls	Medium Pulls	Large Pulls	Pulling Total	Pulling Index	Ryegrass	Browntop	Weeds	Clover	Bare Ground	Other
14	125	3	0	0	0	0	0	45	50	0	0	5	0
14	125	4	0	0	0	0	0	40	60	0	0	0	0
14	125	5	0	0	0	0	0	35	50	10	5	0	0
14	146	1	1	0	0	1	1	80	0	0	0	20	0
14	146	2	3	3	0	6	12	45	30	0	0	25	0
14	146	3	0	0	0	0	0	80	15	0	0	5	0
14	146	4	0	0	0	0	0	75	20	0	0	5	0
14	146	5	0	0	0	0	0	65	25	5	0	5	0
14	147	1	4	0	0	4	4	100	0	0	0	0	0
14	147	2	1	0	0	1	1	85	0	0	0	15	0
14	147	3	6	0	0	6	6	70	0	0	0	30	0
14	147	4	3	0	0	3	3	60	0	0	0	40	0
14	147	5	3	0	0	3	3	65	0	0	0	35	0
14	148	1	0	0	0	0	0	75	20	0	0	5	0
14	148	2	4	4	0	8	16	85	0	0	10	5	0
14	148	3	0	1	0	1	3	45	50	0	5	0	0
14	148	4	1	0	0	1	1	45	30	20	0	5	0
14	148	5	0	1	0	1	3	40	60	0	0	0	0
14	149	1	0	0	0	0	0	20	20	30	5	5	20
14	149	2	0	0	0	0	0	20	20	30	5	5	20
14	149	3	5	0	0	5	5	20	20	30	10	0	20
14	149	4	0	0	0	0	0	20	20	30	10	0	20
14	149	5	0	0	0	0	0	20	20	30	10	0	20
11	A16	1	2	4	0	6	14	25	0	0	10	50	15
11	A16	2	4	1	0	5	7	30	0	0	10	50	10
11	A16	3	3	1	0	4	6	35	0	0	5	40	20
11	A16	4	5	0	0	5	5	45	0	0	5	40	10
11	A16	5	3	0	0	3	3	50	0	5	5	35	5
11	B12	1	0	0	0	0	0	5	30	30	5	0	30
11	B12	2	0	0	0	0	0	0	60	30	0	0	10
11	B12	3	0	0	0	0	0	0	50	50	0	0	0
11	B12	4	0	0	0	0	0	10	40	50	0	0	0
11	B12	5	1	0	0	1	1	10	30	35	5	5	15

14th May 2014

Paddock conditions

Farm	*Paddock*	*Conditions*
15	8	Has not been grazed since last assessment. Pasture long, green, lush. Will be grazed soon.
15	15	Good condition, green grass, not a great deal of pulling. Probably grazed since last assessment.
15	17	Paddock under sown last time we came. Growing back well, clearly defined seed lines 15 cm apart.
9	33	Grazed in last couple of days. Pasture grazed quite short. Some bare patches.
15	35	Pasture long and lush. Has not been grazed in at least 6 weeks.
15	37	Has been grazed since last assessment. Pasture grown back quite long and lush. Still defined rows/clumps. Fresh pulls, quite large ones seen.
14	125	Grazed recently. Pasture condition good. Some fresh pulls
14	146	Paddock recently grazed. Grass thick but has been grazed quite low. Some sort of ploughing or planting has taken place, paddocks have cut lines through them.
14	147	Grazed in last couple of days. Has not been grazed too short. Pasture in good condition, green, lush and thick.
14	148	Recently grazed. Pasture grazed quite short. Good condition.
14	149	Paddock cultivated has been cultivated, no assessment.
9	31B	Has not been grazed since last assessment. Pasture in good condition. Long, green and lush. No assessment.
9	32A	Was being grazed when last assessment undertaken. Pasture long, green and lush. Good condition.
11	A16	Has not been grazed since last assessment. Pasture long and lush, less bare ground. Still lots of chicory.
11	B12	Grazed in last couple of days, quite short. Some pasture still long and lush. Pulls seen outside quadrants.

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
15	15	1	10	1	0	11	13	50	0	5	35	10	0
15	15	2	5	0	0	5	5	60	0	10	25	5	0
15	15	3	3	2	0	5	9	30	0	5	60	5	0
15	15	4	2	0	0	2	2	55	0	15	25	5	0
15	15	5	3	0	0	3	3	75	10	0	15	0	0
9	33	1	0	1	0	1	3	40	40	10	10	0	0
9	33	2	0	0	0	0	0	25	70	0	5	0	0
9	33	3	1	0	0	1	1	25	50	25	0	0	0
9	33	4	10	3	1	14	24	30	20	25	10	15	0
9	33	5	0	1	0	1	3	45	15	30	5	5	0
15	37	1	3	3	1	7	17	60	0	5	5	30	0
15	37	2	0	1	0	1	3	75	0	0	5	20	0

Farm	Paddock	Quadrat	Small Pulls	Medium Pulls	Large Pulls	Pulling Total	Pulling Index	Ryegrass	Browntop	Weeds	Clover	Bare Ground	Other
15	37	3	0	0	0	0	0	75	0	0	5	20	0
15	37	4	4	2	0	6	10	60	0	0	5	35	0
15	37	5	5	3	0	8	14	65	0	10	10	15	0
14	125	1	2	2	1	5	13	50	10	30	10	0	0
14	125	2	1	1	0	2	4	55	25	15	5	0	0
14	125	3	0	0	0	0	0	45	40	10	5	0	0
14	125	4	0	0	0	0	0	40	30	25	5	0	0
14	125	5	1	1	0	2	4	70	10	10	5	5	0
14	146	1	2	0	0	2	2	75	0	10	0	15	0
14	146	2	0	0	0	0	0	70	0	5	0	25	0
14	146	3	1	1	0	2	4	85	0	10	0	5	0
14	146	4	2	1	0	3	5	75	0	5	0	20	0
14	146	5	3	0	0	3	3	85	0	0	0	15	0
14	147	1	0	0	0	0	0	95	0	0	5	0	0
14	147	2	2	0	0	2	2	70	0	0	5	25	0
14	147	3	5	0	0	5	5	75	0	5	0	20	0
14	147	4	2	3	0	5	11	80	0	0	0	20	0
14	147	5	2	0	0	2	2	70	0	20	10	0	0
14	148	1	1	0	0	1	1	75	0	0	0	25	0
14	148	2	1	1	0	2	4	70	10	0	10	10	0
14	148	3	0	1	0	1	3	45	70	5	5	0	5
14	148	4	0	0	0	0	0	45	45	5	5	0	0
14	148	5	1	0	0	1	1	40	60	0	0	0	0
9	32A	1	0	0	0	0	0	60	0	5	25	10	0
9	32A	2	0	0	0	0	0	75	0	5	5	15	0
9	32A	3	0	0	0	0	0	60	0	10	5	20	5
9	32A	4	0	0	0	0	0	75	0	5	5	15	0
9	32A	5	0	1	2	3	13	65	0	10	15	10	0
11	B12	1	0	0	0	0	0	10	15	20	5	0	50
11	B12	2	0	0	0	0	0	25	20	30	5	0	20
11	B12	3	0	0	0	0	0	35	30	30	0	5	0
11	B12	4	0	0	0	0	0	35	30	30	0	5	0
11	B12	5	1	0	0	1	1	35	30	30	0	5	0

6th June 2014

Paddock conditions

Farm	*Paddock*	*Conditions*
15	8	Could not assess because bulls in paddock.
15	15	No assessment, has not been grazed. Pasture quite long and lush, paddock is in quite good condition.
15	17	Pasture growing back quite well. Doesn't seem to be a lot of gaps in between drill lines anymore. Still profound drill lines though.
9	33	No assessment. Pasture long and lush, has not been grazed.
15	35	Grazed recently. Grass very short, patchy, lots of bare ground.
15	37	Was probably grazed just after last assessment. Pasture very long and lush. A couple of recent pulls, but pasture too long for assessment.
14	125	Paddock is in good condition, long thick lush grass but also some fresh pulls so must have been grazed since last assessment.
14	146	No assessment, has not been grazed. Dug a hole, no worms in it.
14	147	Has been grazed since last assessment. Pasture is quite short, longer in urine patches etc., can still see drill lines. Has been pulled bad, in clumps from sowing lines.
14	148	No assessment, has not been grazed. Dug hole, no worms in hole dug.
14	149	Paddock cultivated. Hole dug, ploughed to approx. 20 cm depth.
9	31B	No assessment, pasture long and lush. Has not been grazed in weeks.
9	32A	Pasture long and lush. Has not been grazed in weeks. No assessment.
11	A16	Condition is not good. Pasture grazed recently, quite short, very clumpy and a lot of pulling. Also a lot of bare ground. Manually pulled chicory, was easy to pull then tap root stopped it completely being pulled out. All pulls for this paddock had white roots like they were rotting.
11	B12	Grazed recently. In last couple of days. Quite a lot of fresh pulls around. Pasture patchy, most of it quite short.

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
15	35	1	1	1	0	2	4	65	0	0	0	35	0
15	35	2	1	0	0	1	1	50	0	10	0	40	0
15	35	3	0	1	0	1	3	60	0	0	0	40	0
15	35	4	0	0	0	0	0	60	0	5	0	35	0
15	35	5	1	2	0	3	7	70	0	0	0	30	0
14	125	1	0	1	0	1	3	70	5	5	15	5	0
14	125	2	4	0	0	4	4	80	10	0	5	5	0
14	125	3	0	0	0	0	0	80	0	0	15	5	0
14	125	4	0	0	0	0	0	65	20	10	5	0	0
14	125	5	0	0	0	0	0	80	10	5	5	0	0
14	147	1	5	3	0	8	14	90	0	10	0	0	0
14	147	2	8	3	0	11	17	75	0	5	5	15	0

Farm	Paddock	Quadrat	Small Pulls	Medium Pulls	Large Pulls	Pulling Total	Pulling Index	Ryegrass	Browntop	Weeds	Clover	Bare Ground	Other
14	147	3	5	0	0	5	5	75	0	5	5	15	0
14	147	4	8	2	0	10	14	70	0	15	5	10	0
14	147	5	7	6	1	14	30	70	0	5	10	15	0
11	A16	1	8	6	1	15	31	40	0	0	20	30	10
11	A16	2	1	4	2	7	23	45	0	0	20	20	5
11	A16	3	2	4	0	6	14	75	0	0	10	15	0
11	A16	4	6	7	2	15	37	70	0	0	15	15	0
11	A16	5	5	4	0	9	17	80	0	0	10	10	0
11	B12	1	2	0	1	3	7	35	0	30	0	5	30
11	B12	2	4	0	0	4	4	40	0	30	20	0	10
11	B12	3	10	0	0	10	10	25	25	40	0	0	10
11	B12	4	9	0	0	9	9	35	15	30	5	5	10
11	B12	5	0	0	0	0	0	30	30	30	5	0	5

26th June 2014

Paddock conditions

Farm	Paddock	Conditions
15	8	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
15	15	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
15	17	Still growing back, has not been grazed. Pasture growing back well, can still see drill lines, but gaps are filling with pasture well.
9	33	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
15	35	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
15	37	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
14	125	Grazed in the last couple of weeks. Not sure how heavy it was grazed though. Pasture in good condition, reasonably long.
14	146	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
14	147	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed. Looks like a few cows have grazed the paddock because there is a small amount of fresh cow pats but grass still quite long.
14	148	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
14	149	Paddock cultivated. Pasture starting to grow, however has not been direct drilled - it appears - maybe going to grow a crop?
9	31B	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
9	32A	Cows in paddock so couldn't do assessment.
11	A16	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
11	B12	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
14	125	1	2	0	1	3	7	75	0	5	15	5	0
14	125	2	0	0	0	0	0	40	55	5	0	0	0
14	125	3	2	0	0	2	2	50	50	0	0	0	0
14	125	4	0	0	0	0	0	40	40	15	5	0	0
14	125	5	2	0	0	2	2	35	40	15	5	5	0

15th July 2014

Paddock conditions

Farm	*Paddock*	*Conditions*
15	8	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
15	15	No assessment, has not been grazed since last assessment. Pasture long and lush.
15	17	Recently grazed after being under sown. Visible fresh pulls.
9	33	Just grazed yesterday. Paddock heavily grazed, no grass left. Bare patches of ground.
15	35	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
15	37	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
14	125	No assessment, has not been grazed since last assessment. Pasture long and lush.
14	146	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
14	147	No assessment, has not been grazed since last assessment. Pasture long and lush.
14	148	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
14	149	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
9	31B	Recently grazed in the last couple of days. Not much obvious pulling, paddock hasn't been grazed too low. Quite patchy with a lot of bare patches.
9	32A	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
11	A16	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
11	B12	No assessment, has not been grazed since last assessment. Pasture long and lush.

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
15	17	1	1	0	0	1	1	80	0	10	5	5	0
15	17	2	1	1	0	2	4	90	0	5	0	5	0
15	17	3	3	0	0	3	3	90	0	5	0	5	0
15	17	4	0	0	0	0	0	90	0	5	0	5	0
15	17	5	0	0	0	0	0	85	0	10	0	5	0
9	33	1	4	0	0	4	4	40	0	20	0	40	0
9	33	2	1	0	0	1	1	30	0	0	0	30	40
9	33	3	1	1	0	2	4	30	0	0	0	40	30
9	33	4	1	0	0	1	1	50	0	0	0	40	10
9	33	5	1	0	0	1	1	30	0	0	0	30	20
9	31B	1	1	0	0	1	1	65	0	5	0	30	0
9	31B	2	1	0	0	1	1	65	0	5	0	30	0
9	31B	3	3	2	0	5	9	65	0	5	0	30	0
9	31B	4	3	0	0	3	3	65	0	5	0	30	0
9	31B	5	1	0	0	1	1	80	0	5	0	15	0

8th August 2014

Paddock conditions

Farm	*Paddock*	*Conditions*
15	8	Grazed in the last 3 weeks. Not heavily grazed, pasture growing back long. There are bare patches. Very clumpy grass.
15	15	No assessment, has not been grazed since last assessment. Pasture long and lush.
15	17	No assessment, has not been grazed since last assessment. Pasture long and lush.
9	33	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
15	35	No assessment, has not been grazed since last assessment. Pasture long and lush.
15	37	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
14	125	No assessment, has not been grazed since last assessment. Pasture long and lush.
14	146	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
14	147	No assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
14	148	No assessment, has not been grazed since last assessment. Pasture long and lush.
14	149	no assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
9	31B	no assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
9	32A	no assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.
11	A16	Has been grazed in the last 3 weeks. Lots of pulls, clumpy, starting to grow back now.
11	B12	no assessment, has not been grazed since last assessment. Pasture long and lush, ready to be grazed.

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
15	8	1	1	0	0	1	1	80	0	0	5	15	0
15	8	2	0	0	0	0	0	75	0	0	5	20	0
15	8	3	0	0	1	1	5	65	0	5	5	25	0
15	8	4	1	1	0	2	4	55	0	5	20	20	5
15	8	5	0	2	2	4	16	80	0	5	5	10	0
11	A16	1	2	1	0	3	5	75	0	5	15	5	0
11	A16	2	0	3	0	3	9	75	0	5	15	5	0
11	A16	3	2	4	0	6	14	80	0	5	10	5	0
11	A16	4	1	3	1	5	15	90	0	0	5	5	0
11	A16	5	5	0	0	5	5	85	0	5	0	5	0

28th August 2014

Paddock conditions

Farm	*Paddock*	*Conditions*
15	8	Pasture not grazed since last assessment. Pasture very long, green and lush.
15	15	Pasture not assessed because the paddock was being grazed.
15	17	Has not been grazed. Pasture growing back, not that long. Not patchy.
9	33	Paddock grazed recently (last couple of days). Fed maize feed also. And palm kernel. Doesn't look like a lot of pulling.
15	35	Pasture not grazed since last assessment. Pasture very long, green and lush.
15	37	Been grazed in the last couple of weeks. Growing back. Not obvious signs of pulling
14	125	Pasture not grazed since last assessment. Pasture very long, green and lush.
14	146	Paddock has been grazed in the last 3 weeks. Not heavily grazed. Pulling dosen't appear to be bad.
14	147	Pasture not grazed since last assessment. Pasture very long, green and lush.
14	148	Grazed in the last week, quite heavy. Also looks like it had supplementary feed. Hay etc. present in paddock.
14	149	Pasture still growing back from cultivation. Pasture has started to grow finally. Looks to be broadcast sown. Still quite patchy.
9	31B	Paddock Being Grazed so could not be assessed.
9	32A	Pasture has been grazed since last time as there are fresh pulls, but the pasture has grown back quite long and lush.
11	A16	Pasture not grazed since last assessment. Pasture growing back well, looks patchy and clumpy though. Very uneven surface.
11	B12	Pasture not grazed since last assessment. Pasture very long, green and lush.

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
9	33	1	0	0	0	0	0	90	0	5	5	0	0
9	33	2	0	0	0	0	0	45	0	5	0	20	30
9	33	3	2	0	0	2	2	25	0	10	0	40	25
9	33	4	1	0	0	1	1	60	0	10	0	5	25
9	33	5	0	1	0	1	3	70	0	10	5	5	20
15	37	1	0	0	0	0	0	80	0	10	0	10	0
15	37	2	0	0	0	0	0	70	0	10	0	20	0
15	37	3	1	0	0	1	1	80	0	15	0	5	0
15	37	4	0	0	0	0	0	60	0	15	5	20	0
15	37	5	0	0	0	0	0	85	0	5	5	5	0
14	146	1	0	2	0	2	6	70	20	0	0	10	0
14	146	2	3	0	0	3	3	80	15	0	0	5	0

Farm	Paddock	Quadrat	Small Pulls	Medium Pulls	Large Pulls	Pulling Total	Pulling Index	Ryegrass	Browntop	Weeds	Clover	Bare Ground	Other
14	146	3	0	0	0	0	0	95	0	0	0	5	0
14	146	4	2	1	0	3	5	95	0	0	0	5	0
14	146	5	1	0	0	1	1	80	15	0	0	5	0
14	148	1	0	0	0	0	0	60	30	0	0	0	10
14	148	2	0	0	0	0	0	60	30	0	0	10	0
14	148	3	0	0	0	0	0	50	50	0	0	0	0
14	148	4	1	0	0	1	1	50	50	0	0	0	0
14	148	5	2	1	0	3	5	45	40	0	0	15	0
9	32A	1	0	0	1	1	5	80	0	0	5	15	0
9	32A	2	2	0	0	2	2	75	0	0	5	20	0
9	32A	3	0	0	0	0	0	85	0	5	0	10	0
9	32A	4	1	0	0	1	1	90	0	5	0	5	0
9	32A	5	0	1	0	1	3	90	0	5	0	5	0

18th September 2014

Paddock conditions

Farm	Paddock	Conditions
15	8	Been grazed in the last week. Not heavily though. Some pulling around
15	15	Pasture quite long and lush. Has grown quickly since last grazing (3 weeks ago). No immediate signs of pulling, lots of clover now. Grass may be too long to see pulls from last graze.
15	17	Pasture grazed recently, dosent look heavily though. Dosent appear to be pulling. Grazed by bulls perhaps.
9	33	Paddock not assessed because has not been grazed since last assessment.
15	35	Has been grazed since last assessment. Pasture quite long though. No obvious signs of pulling.
15	37	Paddock not assessed because has not been grazed since last assessment.
14	125	Has been grazed since last assessment. Pasture not that long, dosent appear to be a lot of pulling
14	146	Pasture has been grazed in last week. Quite short, signs of abit of pulling.
14	147	Pasture grazed since last assessment, but not heavily. Parts quite long. Still see signs of pulling.
14	148	Paddock recently grazed. Grazed back quite low. Dosent appear to be lots of pulling.
14	149	Paddock has been lightly grazed, mostly taken pasture around edges. Pasture that is growing back appears to be nibbled, no pulling of this.
9	31B	Paddock not assessed because has not been grazed since last assessment.
9	32A	Paddock not assessed because has not been grazed since last assessment.
11	A16	Paddock not assessed because has not been grazed since last assessment.
11	B12	Paddock not assessed because has not been grazed since last assessment

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
15	8	1	1	0	0	1	1	70	0	15	15	0	0
15	8	2	0	0	0	0	0	65	0	15	15	5	0
15	8	3	0	1	0	1	3	70	0	10	5	10	5
15	8	4	1	3	0	4	10	70	0	5	10	10	5
15	8	5	0	0	0	0	0	90	0	5	5	5	0
15	15	1	0	0	0	0	0	50	0	10	20	0	20
15	15	2	1	0	0	1	1	50	0	10	20	0	20
15	15	3	0	0	0	0	0	45	0	30	25	0	0
15	15	4	0	0	0	0	0	50	0	10	40	0	0
15	15	5	0	0	0	0	0	70	0	10	20	0	0
15	17	1	0	0	0	0	0	50	0	10	15	0	25
15	17	2	3	0	0	3	3	50	0	15	10	5	20
15	17	3	1	0	0	1	1	40	0	10	5	0	15
15	17	4	1	0	0	1	1	60	0	15	15	0	20
15	17	5	1	0	0	1	1	60	0	15	5	5	15
15	35	1	1	0	0	1	1	90	0	0	0	10	0
15	35	2	0	0	0	0	0	90	0	0	0	10	0
15	35	3	0	0	0	0	0	95	0	0	0	5	0
15	35	4	0	0	0	0	0	95	0	0	0	5	0
15	35	5	0	1	0	1	3	85	0	5	0	10	0
14	125	1	2	0	0	2	2	60	35	5	0	0	0
14	125	2	0	0	0	0	0	65	20	10	5	0	0
14	125	3	2	0	0	2	2	40	55	5	0	0	0
14	125	4	0	0	0	0	0	40	40	5	5	0	0
14	125	5	0	0	0	0	0	40	40	5	0	5	0
14	146	1	1	0	0	1	1	90	0	5	0	5	0
14	146	2	2	0	0	2	2	80	0	5	0	15	0
14	146	3	1	0	0	1	1	95	0	0	0	5	0
14	146	4	2	0	0	2	2	95	0	5	0	0	0
14	146	5	0	0	0	0	0	80	0	0	5	15	0
14	147	1	2	0	0	2	2	95	0	0	5	0	0
14	147	2	0	0	0	0	0	80	0	5	10	5	0
14	147	3	1	0	0	1	1	80	0	15	5	0	0

Farm	Paddock	Quadrat	Small Pulls	Medium Pulls	Large Pulls	Pulling Total	Pulling Index	Ryegrass	Browntop	Weeds	Clover	Bare Ground	Other
14	147	4	0	0	0	0	0	85	0	5	5	5	0
14	147	5	1	0	0	1	1	80	0	15	5	0	0
14	148	1	0	0	0	0	0	55	30	0	5	10	0
14	148	2	0	0	0	0	0	60	20	0	0	20	0
14	148	3	0	0	0	0	0	35	60	0	0	5	0
14	148	4	0	0	0	0	0	35	60	0	0	5	0
14	148	5	1	0	0	1	1	40	50	0	5	5	0

9th October 2014

Paddock conditions

Farm	Paddock	Conditions
15	8	Recently grazed quite heavy. Lots of pulls around. Bare patches.
15	15	Recently been grazed, and looks to also have been weed sprayed because grass is pale. Pulls visible.
15	17	Paddock not assessed because has not been grazed since last assessment.
9	33	Has not been grazed since last assessment. Pasture thick, green and lush.
15	35	Paddock not assessed because has not been grazed since last assessment.
15	37	Paddock not assessed because has not been grazed since last assessment.
14	125	Recently grazed. Pasture growing back, not many pulls around. Grass quite short.
14	146	Has not been grazed since last assessment. Pasture thick, green and lush.
14	147	Pasture has been grazed since last assessment. Not that long, a few pulls around
14	148	Has not been grazed since last assessment. Pasture thick, green and lush.
14	149	Not been grazed - ploughed paddock. Pasture growing back but mostly weeds - possibly going to plant crops?
9	31B	Pasture has been grazed recently. Pulls around. Overall pasture in good condition.
9	32A	Has not been grazed since last assessment. Pasture thick, green and lush.
11	A16	Paddock not assessed because has not been grazed since last assessment.
11	B12	Paddock not assessed because has not been grazed since last assessment.

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
15	8	1	4	0	0	4	4	65	0	10	15	10	0
15	8	2	2	0	0	2	2	70	0	15	10	5	0
15	8	3	4	1	0	5	7	55	0	5	10	30	0
15	8	4	4	0	0	4	4	65	0	10	10	15	0
15	8	5	3	1	0	4	6	85	0	5	5	5	0
15	15	1	0	0	0	0	0	35	40	15	10	0	0
15	15	2	1	0	0	1	1	35	40	15	10	0	0
15	15	3	2	0	0	2	2	30	30	10	15	10	0
15	15	4	2	0	0	2	2	35	35	10	10	10	0
15	15	5	1	0	0	1	1	40	40	10	10	0	0
14	125	1	2	0	0	2	2	40	40	15	5	0	0
14	125	2	0	0	0	0	0	45	45	10	0	0	0
14	125	3	3	0	0	3	3	45	45	10	0	0	0
14	125	4	0	0	0	0	0	45	45	10	0	0	0
14	125	5	0	0	0	0	0	40	40	20	0	0	0
14	147	1	2	0	0	2	2	85	0	5	10	0	0
14	147	2	0	0	0	0	0	80	0	5	15	0	0
14	147	3	0	0	0	0	0	70	0	20	10	0	0
14	147	4	2	1	0	3	5	80	0	10	5	5	0
14	147	5	4	0	0	4	4	75	0	15	10	0	0
9	31B	1	2	0	0	2	2	80	0	10	5	5	0
9	31B	2	6	1	0	7	9	85	0	5	5	5	0
9	31B	3	2	0	0	2	2	90	0	0	5	5	0
9	31B	4	2	0	0	2	2	90	0	5	0	5	0
9	31B	5	6	0	0	6	6	95	0	5	0	0	0

30th October 2014

Paddock conditions

Farm	*Paddock*	*Conditions*
15	8	Paddock being grazed at present.
15	15	Paddock cultivated. Looks to be ripped to 15-20 cm depth approx.
15	17	Paddock has been grazed since last assessment, but must have been at least 2 weeks ago as pasture has grown back quite a bit. Not many bare patches, no pulls around.
9	33	Has been grazed since last assessment, but grown back quickly. In quite good condition.
15	35	No assessment because paddock has not been grazed in weeks. Pasture very long and lush.
15	37	Paddock only just been grazed. Not grazed too heavy, looks to be some pulling around.
14	125	Pasture recently grazed. Quite short, pulls around.
14	146	No assessment as paddock has not been grazed in weeks. Pasture really long and lush. Possibly going to make silage?
14	147	Grazed since last assessment. Grown back quick. Looks like not many pulls about, pasture quite long now.
14	148	No assessment as paddock has not been grazed in weeks. Pasture really long and lush. Possibly going to make silage?
14	149	No assessment because paddock has not been grazed (cultivated paddock). Heaps of weeds, not a lot of actual grass around. Quite long.
9	31B	Has been grazed since last assessment, but grown back quickly. Obvious pulls around. In quite good condition
9	32A	Pasture recently grazed. Starting to grow back, in quite good condition
11	A16	Pasture recently grazed. Quite patchy, a lot of pulls around. Bare patches also. Lots of pulls in this paddock, lots that were reattaching themselves to the soil, lots that didn't make it to the transect
11	B12	No assessment as paddock has not been grazed in weeks. Pasture really long and lush. Possibly going to make silage?

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
15	17	1	0	0	0	0	0	70	0	10	20	0	0
15	17	2	0	0	0	0	0	70	0	15	15	0	0
15	17	3	0	0	0	0	0	80	0	10	10	0	0
15	17	4	0	0	0	0	0	80	0	10	10	0	0
15	17	5	0	0	0	0	0	65	0	15	20	0	0
9	33	1	2	1	0	3	5	90	0	0	10	0	0
9	33	2	1	0	0	1	1	30	0	5	5	0	50
9	33	3	1	1	0	2	4	70	0	0	10	0	20
9	33	4	0	0	0	0	0	75	0	15	10	0	0
9	33	5	1	0	0	1	1	70	0	0	10	0	20
15	37	1	0	0	0	0	0	90	0	5	0	5	0

Farm	Paddock	Quadrat	Small Pulls	Medium Pulls	Large Pulls	Pulling Total	Pulling Index	Ryegrass	Browntop	Weeds	Clover	Bare Ground	Other
15	37	2	0	0	0	0	0	90	0	0	0	10	0
15	37	3	0	0	0	0	0	80	0	0	5	15	0
15	37	4	0	0	0	0	0	85	0	5	5	5	0
15	37	5	2	0	0	2	2	65	0	20	15	0	0
14	125	1	0	0	0	0	0	45	45	10	0	0	0
14	125	2	2	0	0	2	2	45	45	5	5	0	0
14	125	3	4	0	0	4	4	50	40	5	5	0	0
14	125	4	2	0	0	2	2	45	50	5	0	0	0
14	125	5	1	0	0	1	1	50	45	5	0	0	0
14	147	1	1	0	0	1	1	95	0	0	5	0	0
14	147	2	4	1	0	5	7	75	0	5	20	0	0
14	147	3	0	0	0	0	0	75	0	15	5	5	0
14	147	4	2	0	0	2	2	90	0	0	5	5	0
14	147	5	2	0	0	2	2	95	0	0	5	0	0
9	31B	1	2	0	0	2	2	85	0	0	10	5	0
9	31B	2	4	0	0	4	4	80	0	0	0	0	20
9	31B	3	4	1	0	5	7	95	0	0	5	0	0
9	31B	4	4	0	0	4	4	90	0	0	5	5	0
9	31B	5	4	0	0	4	4	90	0	0	5	5	0
9	32A	1	0	2	1	3	11	95	0	0	0	5	0
9	32A	2	5	0	0	5	5	85	0	5	0	10	0
9	32A	3	1	0	0	1	1	85	0	0	0	15	0
9	32A	4	1	0	0	1	1	90	0	5	0	5	0
9	32A	5	2	0	0	2	2	95	0	0	0	5	0
11	A16	1	0	0	0	0	0	60	0	5	30	5	0
11	A16	2	1	0	0	1	1	70	0	5	25	0	0
11	A16	3	0	0	1	1	5	75	0	10	15	0	0
11	A16	4	2	1	0	3	5	75	0	0	25	0	0
11	A16	5	0	0	0	0	0	90	0	5	5	0	0

20th November 2014

Paddock conditions

Farm	*Paddock*	*Conditions*
15	8	Paddock grazed on the day we were down last, so hasn't been grazed for 3 weeks. Pasture very long and lush, quite a bit of clover around now and chicory still in paddock. No obvious pulling.
15	15	Paddock got cultivated last time we were down. Paddock sown into crop - looks like maize.
15	17	Has been grazed since last assessment, but grown back quite quickly. Pasture long, doesn't seem to be many pulls, if any.
9	33	Pasture long and thick but has been grazed since last time (fresh poo) a couple of pulls about but relatively good condition.
15	35	Pasture has been grazed since last assessment, probably been about 2 weeks. Pasture good condition, not a lot of pulling.
15	37	Paddock not assessed because has not been grazed since last assessment. Going to be grazed in next couple of days, break fence being put up. Pasture very long and lush.
14	125	Just grazed in last couple of days. Pasture not grazed too heavy, still a few long patches of grass - not much pulling about.
14	146	Paddock has been mowed for silage. Pasture now very short and even as recently been done.
14	147	Paddock not grazed since last assessment. Pasture long and lush, good condition.
14	148	Paddock has been mowed for silage. Pasture now very short and even as recently been done.
14	149	Paddock that got plowed. Still no grazing, no grass planted just full of weeds.
9	31B	Paddock been grazed since last assessment. But has grown back a fair bit, starting to get quite long. A few pulls around.
9	32A	Paddock has not been grazed since last assessment. Pasture very long and lush, thick and in good condition.
11	A16	Grazed since last assessment. Grass not that long, pulling around, and a few bare patches.
11	B12	Has been grazed since last assessment. Pasture in good condition, don't see a lot of pulling around.

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
15	8	1	0	0	0	0	0	90	0	0	5	5	0
15	8	2	1	0	0	1	1	80	0	5	10	5	0
15	8	3	0	1	1	2	8	95	0	0	10	5	0
15	8	4	0	0	0	0	0	65	0	5	20	10	0
15	8	5	1	0	0	1	1	80	0	0	15	0	5
15	17	1	0	0	0	0	0	70	0	10	20	0	0
15	17	2	0	0	0	0	0	75	0	10	15	0	0
15	17	3	0	0	0	0	0	85	0	5	10	0	0
15	17	4	0	0	0	0	0	75	0	5	15	5	0
15	17	5	0	0	0	0	0	90	0	0	5	5	0
9	33	1	2	0	0	2	2	80	0	5	15	0	0

Farm	Paddock	Quadrat	Small Pulls	Medium Pulls	Large Pulls	Pulling Total	Pulling Index	Ryegrass	Browntop	Weeds	Clover	Bare Ground	Other
9	33	2	0	0	0	0	0	40	0	0	10	0	50
9	33	3	1	0	0	1	1	55	0	0	10	0	35
9	33	4	0	0	0	0	0	50	0	10	10	0	30
9	33	5	0	0	0	0	0	50	0	15	10	15	10
15	35	1	0	0	0	0	0	90	0	0	0	5	0
15	35	2	0	0	0	0	0	90	0	5	5	5	0
15	35	3	0	0	0	0	0	90	0	0	0	5	0
15	35	4	0	0	0	0	0	80	0	10	10	5	0
15	35	5	0	0	0	0	0	85	0	5	5	5	0
14	125	1	0	0	0	0	0	45	30	20	5	0	0
14	125	2	1	0	0	1	1	40	40	15	5	0	0
14	125	3	3	0	0	3	3	50	35	10	5	0	0
14	125	4	1	0	0	1	1	50	45	5	0	0	0
14	125	5	2	0	0	2	2	50	30	15	5	0	0
9	31B	1	3	0	0	3	3	85	0	5	10	0	0
9	31B	2	4	1	0	5	7	90	0	5	5	0	0
9	31B	3	3	3	0	6	12	95	0	0	5	0	0
9	31B	4	0	0	0	0	0	95	0	0	5	0	0
9	31B	5	2	0	0	2	2	85	0	10	5	0	0
11	A16	1	0	0	0	0	0	40	0	10	50	0	0
11	A16	2	0	1	1	2	8	80	0	0	15	5	0
11	A16	3	1	1	0	2	4	80	0	0	10	5	5
11	A16	4	0	0	0	0	0	90	0	5	5	0	0
11	A16	5	1	0	0	1	1	90	0	0	5	0	5
11	B12	1	0	0	0	0	0	30	30	10	15	0	15
11	B12	2	0	0	0	0	0	40	15	10	15	0	20
11	B12	3	0	0	0	0	0	40	15	25	5	0	5
11	B12	4	0	0	0	0	0	50	25	20	0	5	0
11	B12	5	0	0	0	0	0	50	15	25	10	0	0

11th December 2014

Paddock conditions

Farm	*Paddock*	*Conditions*
15	8	Paddock grazed since last assessment. Maybe 1-2 weeks ago. Pulling around, a bit of patchy bare ground.
15	15	Paddock cultivated, maize sown. Maize growing very quickly.
15	17	Paddock has been grazed since last assessment. But has grown back a bit. Looks in good condition, not a lot of pulling around.
9	33	Paddock grazed since last assessment. Pasture grown back, doesn't appear to be many pulls around.
15	35	Paddock only grazed in last couple of days. Pasture quite short, but paddock condition good. No pulling around.
15	37	Pasture too long to be assessed. Good condition, no pulls about. Been a while since last grazing.
14	125	Paddock good condition, grazed in last week or so. Some pulling but not much.
14	146	Paddock not grazed so no assessment. Mowed last time and hasn't been grazed since as still growing back.
14	147	Paddock been grazed in the last couple of weeks. Pasture condition looks good, a few pulls around.
14	148	Paddock not grazed so no assessment. Mowed last time and hasn't been grazed since as still growing back.
14	149	Plowed paddock. Been Sprayed, grass and weeds all dying.
9	31B	Paddock not grazed so no assessment. Pasture very long, going into seed.
9	32A	Paddock grazed since last assessment. Pasture grazed in last week. Not too short. Some pulling around.
11	A16	Paddock not grazed so no assessment. Pasture long and lush.
11	B12	Paddock not grazed so no assessment. Pasture long and lush.

Assessed paddocks

Farm	*Paddock*	*Quadrat*	*Small Pulls*	*Medium Pulls*	*Large Pulls*	*Pulling Total*	*Pulling Index*	*Ryegrass*	*Browntop*	*Weeds*	*Clover*	*Bare Ground*	*Other*
15	8	1	0	1	0	1	3	90	0	0	5	5	0
15	8	2	2	1	0	3	5	75	0	0	15	10	0
15	8	3	2	1	0	3	5	55	0	0	20	25	0
15	8	4	0	0	0	0	0	60	0	0	30	10	0
15	8	5	2	0	0	2	2	75	0	0	15	10	0
15	17	1	1	0	0	1	1	80	0	5	15	0	0
15	17	2	1	0	0	1	1	90	0	0	10	0	0
15	17	3	0	0	0	0	0	90	0	0	5	5	0
15	17	4	2	0	0	2	2	60	0	5	30	5	0
15	17	5	0	0	0	0	0	80	0	5	15	0	0
9	33	1	5	1	0	6	8	55	0	10	25	0	10
9	33	2	0	0	3	3	15	20	0	10	10	0	40

Farm	Paddock	Quadrat	Small Pulls	Medium Pulls	Large Pulls	Pulling Total	Pulling Index	Ryegrass	Browntop	Weeds	Clover	Bare Ground	Other
9	33	3	3	1	0	4	6	60	20	5	10	0	5
9	33	4	0	0	0	0	0	50	20	20	5	0	5
9	33	5	0	0	0	0	0	65	20	5	10	0	0
15	35	1	0	0	0	0	0	85	0	0	5	10	0
15	35	2	0	0	0	0	0	70	0	10	5	15	0
15	35	3	0	0	0	0	0	90	0	0	5	5	0
15	35	4	0	0	0	0	0	85	0	5	5	5	0
15	35	5	0	0	0	0	0	85	0	0	5	10	0
14	125	1	3	0	0	3	3	50	30	10	10	0	0
14	125	2	0	0	0	0	0	45	25	20	10	0	0
14	125	3	3	0	0	3	3	50	35	10	5	0	0
14	125	4	2	0	0	2	2	45	40	10	5	0	0
14	125	5	1	0	0	1	1	35	50	10	5	0	0
14	147	1	0	0	0	0	0	90	0	0	10	0	0
14	147	2	7	1	0	8	10	70	0	5	25	0	0
14	147	3	3	0	0	3	3	75	0	10	15	0	0
14	147	4	7	0	0	7	7	85	0	5	10	0	0
14	147	5	3	0	0	3	3	75	0	10	15	0	0
9	32A	1	6	3	1	10	20	80	0	5	5	10	0
9	32A	2	3	1	0	4	6	80	0	5	10	5	0
9	32A	3	0	1	0	1	3	80	0	5	5	10	0
9	32A	4	2	3	0	5	11	85	0	0	0	15	0
9	32A	5	1	3	0	4	10	65	0	10	15	10	0

Appendix 4 – Soil Bulk Density and Soil Moisture Measurements

Summer

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
1	13/01/2014	15	8	Ap 0-5	126.280	145	6.557	5.297	23.787	1.238	102.014	0.722
2	13/01/2014	15	8	Ap 0-5	144.490	146	6.567	4.830	35.963	1.360	106.272	0.752
3	13/01/2014	15	8	Ap 0-5	150.400	147	6.852	4.980	37.590	1.376	109.310	0.773
4	13/01/2014	15	8	Ap 5-10	141.980	148	6.080	4.325	40.578	1.406	100.997	0.714
5	13/01/2014	15	8	Ap 5-10	138.710	149	6.499	4.518	43.847	1.438	96.429	0.682
6	13/01/2014	15	8	Ap 5-10	133.210	150	6.486	4.746	36.662	1.367	97.474	0.689
7	13/01/2014	15	8	Bw 10-20	135.840	151	6.227	4.479	39.027	1.390	97.708	0.691
8	13/01/2014	15	8	Bw 10-20	128.390	152	6.816	4.974	37.033	1.370	93.693	0.663
9	13/01/2014	15	8	Bw 10-20	133.370	153	6.692	4.651	43.883	1.439	92.693	0.656
10	13/01/2014	15	8	Bah 20-30	127.400	154	6.563	4.428	48.216	1.482	85.956	0.608
11	13/01/2014	15	8	Bah 20-30	129.420	155	6.491	4.211	54.144	1.541	83.961	0.594
12	13/01/2014	15	8	Bah 20-30	138.320	156	6.674	4.458	49.708	1.497	92.393	0.654
13	21/01/2014	15	15	Ap 0-5	115.861	145	5.273	4.432	18.976	1.190	97.382	0.689
14	21/01/2014	15	15	Ap 0-5	126.999	146	5.364	4.080	31.471	1.315	96.599	0.683
15	21/01/2014	15	15	Ap 0-5	118.218	147	6.993	5.831	19.928	1.199	98.574	0.697
16	21/01/2014	15	15	Ap 5-10	120.326	148	9.138	8.083	13.052	1.131	106.434	0.753
17	21/01/2014	15	15	Ap 5-10	134.431	149	8.875	7.820	13.491	1.135	118.451	0.838
18	21/01/2014	15	15	Ap 5-10	121.371	150	7.903	7.019	12.594	1.126	107.795	0.762
19	21/01/2014	15	15	Bah 10-20	132.132	151	6.586	5.983	10.633	1.106	119.432	0.845
20	21/01/2014	15	15	Bah 10-20	138.321	152	6.979	6.346	9.975	1.100	125.775	0.890
21	21/01/2014	15	15	Bah 10-20	138.932	153	8.094	7.487	8.107	1.081	128.513	0.909
22	21/01/2014	15	15	Cu1 20-30	121.050	154	5.967	5.260	13.441	1.134	106.707	0.755
23	21/01/2014	15	15	Cu1 20-30	139.792	155	7.831	7.301	7.259	1.073	130.331	0.922
24	21/01/2014	15	15	Cu1 20-30	124.143	156	8.609	8.272	4.074	1.041	119.283	0.844
25	22/01/2014	11	B12	Ap 0-5	137.452	157	7.114	4.875	45.928	1.459	94.192	0.666
26	22/01/2014	11	B12	Ap 0-5	145.388	158	6.802	4.857	40.045	1.400	103.815	0.734
27	22/01/2014	11	B12	Ap 0-5	116.237	159	6.689	5.131	30.364	1.304	89.163	0.631

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
28	22/01/2014	11	B12	Ap 5-10	127.640	160	5.790	5.096	13.619	1.136	112.341	0.795
29	22/01/2014	11	B12	Ap 5-10	125.100	161	5.644	4.979	13.356	1.134	110.360	0.781
30	22/01/2014	11	B12	Ap 5-10	124.871	162	5.615	4.893	14.756	1.148	108.815	0.770
31	22/01/2014	11	B12	Bw 10-20	126.410	163	7.251	6.683	8.499	1.085	116.508	0.824
32	22/01/2014	11	B12	Bw 10-20	131.615	164	7.201	6.638	8.481	1.085	121.325	0.858
33	22/01/2014	11	B12	Bw 10-20	116.312	165	8.185	7.498	9.162	1.092	106.549	0.754
34	22/01/2014	11	B12	No Samples								
35	22/01/2014	11	B12	No Samples								
36	22/01/2014	11	B12	No Samples								
37	22/01/2014	15	37	Ap 0-5	142.252	109	5.914	4.030	46.749	1.467	96.935	0.686
38	22/01/2014	15	37	Ap 0-5	135.592	110	5.986	4.161	43.860	1.439	94.253	0.667
39	22/01/2014	15	37	Ap 0-5	154.795	111	5.506	3.829	43.797	1.438	107.648	0.761
40	22/01/2014	15	37	Ap 5-10	148.390	112	6.203	4.320	43.588	1.436	103.344	0.731
41	22/01/2014	15	37	Ap 5-10	152.475	113	6.631	4.702	41.025	1.410	108.119	0.765
42	22/01/2014	15	37	Ap 5-10	155.563	114	6.495	4.626	40.402	1.404	110.798	0.784
43	22/01/2014	15	37	Bw 10-20	120.550	115	7.645	5.545	37.872	1.379	87.436	0.618
44	22/01/2014	15	37	Bw 10-20	126.450	116	5.751	4.356	32.025	1.320	95.777	0.677
45	22/01/2014	15	37	Bw 10-20	128.745	117	6.223	4.621	34.668	1.347	95.602	0.676
46	22/01/2014	15	37	Bw 20-30	135.486	118	5.456	4.240	28.679	1.287	105.290	0.745
47	22/01/2014	15	37	Bw 20-30	130.694	119	5.596	4.255	31.516	1.315	99.375	0.703
48	22/01/2014	15	37	Bw 20-30	131.386	120	5.889	4.370	34.760	1.348	97.496	0.690
49	22/01/2014	15	35	Ap 0-5	145.489	133	5.127	3.746	36.866	1.369	106.300	0.752
50	22/01/2014	15	35	Ap 0-5	140.800	134	7.115	4.996	42.414	1.424	98.867	0.699
51	22/01/2014	15	35	Ap 0-5	140.376	135	5.880	4.186	40.468	1.405	99.934	0.707
52	22/01/2014	15	35	Ap 5-10	130.136	136	6.439	4.870	32.218	1.322	98.426	0.696
53	22/01/2014	15	35	Ap 5-10	134.734	137	6.640	4.925	34.822	1.348	99.934	0.707
54	22/01/2014	15	35	Ap 5-10	137.509	138	5.434	4.000	35.850	1.359	101.221	0.716
55	22/01/2014	15	35	Bw 10-20	120.286	139	6.024	5.064	18.957	1.190	101.117	0.715
56	22/01/2014	15	35	Bw 10-20	122.267	140	5.394	4.599	17.286	1.173	104.247	0.737
57	22/01/2014	15	35	Bw 10-20	129.510	141	6.313	5.309	18.911	1.189	108.913	0.770
58	22/01/2014	15	35	Cu 20-30	142.338	142	7.482	6.319	18.405	1.184	120.213	0.850
59	22/01/2014	15	35	Cu 20-30	132.127	143	7.875	6.513	20.912	1.209	109.275	0.773
60	22/01/2014	15	35	Cu 20-30	124.514	144	8.208	6.865	19.563	1.196	104.141	0.737
61	23/01/2014	14	147	Ap 0-5	112.432	73	5.682	4.144	37.114	1.371	81.999	0.580

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
62	23/01/2014	14	147	Ap 0-5	119.319	74	5.532	4.056	36.391	1.364	87.483	0.619
63	23/01/2014	14	147	Ap 0-5	125.059	75	5.532	4.158	33.045	1.330	93.998	0.665
64	23/01/2014	14	147	Ap 5-10	116.759	76	5.684	4.995	13.794	1.138	102.606	0.726
65	23/01/2014	14	147	Ap 5-10	118.160	77	5.259	4.234	24.209	1.242	95.130	0.673
66	23/01/2014	14	147	Ap 5-10	122.397	78	5.569	4.599	21.092	1.211	101.078	0.715
67	23/01/2014	14	147	Ap 10-20	120.718	79	5.391	4.130	30.533	1.305	92.481	0.654
68	23/01/2014	14	147	Ap 10-20	123.493	80	5.345	3.741	42.876	1.429	86.434	0.611
69	23/01/2014	14	147	Ap 10-20	128.676	81	5.711	4.331	31.863	1.319	97.583	0.690
70	23/01/2014	14	147	Bw 22-30	119.089	82	5.505	4.200	31.071	1.311	90.858	0.643
71	23/01/2014	14	147	Bw 22-30	129.445	83	6.440	4.959	29.865	1.299	99.677	0.705
72	23/01/2014	14	147	Bw 22-30	142.345	84	6.999	5.510	27.024	1.270	112.062	0.793
73	23/01/2014	14	149	Ap 0-5	137.946	121	5.504	3.704	48.596	1.486	92.833	0.657
74	23/01/2014	14	149	Ap 0-5	141.563	122	6.469	4.583	41.152	1.412	100.291	0.709
75	23/01/2014	14	149	Ap 0-5	135.435	123	6.996	4.690	49.168	1.492	90.793	0.642
76	23/01/2014	14	149	Ap 5-10	123.809	124	6.336	5.407	17.181	1.172	105.656	0.747
77	23/01/2014	14	149	Ap 5-10	124.027	125	6.498	5.420	19.889	1.199	103.451	0.732
78	23/01/2014	14	149	Ap 5-10	121.999	126	6.958	5.818	19.594	1.196	102.011	0.722
79	23/01/2014	14	149	Bw 10-22	138.235	127	6.546	5.260	24.449	1.244	111.078	0.786
80	23/01/2014	14	149	Bw 10-22	127.290	128	9.158	8.180	11.956	1.120	113.696	0.804
81	23/01/2014	14	149	Bw 10-22	137.784	129	9.154	7.506	21.956	1.220	112.979	0.799
82	23/01/2014	14	149	Cu 22- 30	127.939	130	8.236	7.041	16.972	1.170	109.376	0.774
83	23/01/2014	14	149	Cu 22- 30	138.325	131	8.923	7.505	18.894	1.189	116.343	0.823
84	23/01/2014	14	149	Cu 22- 30	113.505	132	5.825	4.552	27.966	1.280	88.700	0.627
85	22/01/2014	14	146	Ap 0-5	139.021	61	5.294	3.945	34.195	1.342	103.596	0.733
86	22/01/2014	14	146	Ap 0-5	149.970	62	6.817	5.159	32.138	1.321	113.495	0.803
87	22/01/2014	14	146	Ap 0-5	138.902	63	6.081	4.762	27.698	1.277	108.773	0.769
88	22/01/2014	14	146	Ap 5-10	122.154	64	5.888	4.953	18.877	1.189	102.756	0.727
89	22/01/2014	14	146	Ap 5-10	135.489	65	6.870	5.719	20.126	1.201	112.789	0.798
90	22/01/2014	14	146	Ap 5-10	117.925	66	5.812	4.730	22.875	1.229	95.971	0.679
91	22/01/2014	14	146	Ap2 10-15	121.078	67	6.070	5.236	15.928	1.159	104.442	0.739
92	22/01/2014	14	146	Ap2 10-15	119.181	68	6.222	5.328	16.779	1.168	102.057	0.722
93	22/01/2014	14	146	Ap2 10-15	124.177	69	6.777	5.702	18.853	1.189	104.479	0.739
94	22/01/2014	14	146	Bw 15-28	115.277	70	7.512	6.282	19.580	1.196	96.402	0.682
95	22/01/2014	14	146	Bw 15-28	122.926	71	7.152	6.072	17.787	1.178	104.363	0.738

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
96	22/01/2014	14	146	Bw 15-28	121.832	72	6.211	5.178	19.950	1.199	101.569	0.718
97	23/01/2014	14	148	Ap 0-5	124.480	85	5.984	4.953	20.816	1.208	103.033	0.729
98	23/01/2014	14	148	Ap 0-5	131.451	86	6.026	4.779	26.093	1.261	104.249	0.737
99	23/01/2014	14	148	Ap 0-5	123.141	87	5.576	4.519	23.390	1.234	99.798	0.706
100	23/01/2014	14	148	Ap 5-10	132.859	88	5.565	4.716	18.003	1.180	112.590	0.796
101	23/01/2014	14	148	Ap 5-10	120.692	89	6.938	5.842	18.761	1.188	101.626	0.719
102	23/01/2014	14	148	Ap 5-10	132.790	90	5.905	5.021	17.606	1.176	112.911	0.799
103	23/01/2014	14	148	Bw1 10-20	127.980	91	6.392	5.166	23.732	1.237	103.433	0.732
104	23/01/2014	14	148	Bw1 10-20	128.958	92	6.347	5.397	17.602	1.176	109.656	0.776
105	23/01/2014	14	148	Bw1 10-20	143.379	93	5.961	4.976	19.795	1.198	119.687	0.847
106	23/01/2014	14	148	Bw2 20-30	145.776	94	7.217	5.872	22.905	1.229	118.608	0.839
107	23/01/2014	14	148	Bw2 20-30	163.681	95	8.056	6.592	22.209	1.222	133.936	0.947
108	23/01/2014	14	148	Bw2 20-30	165.199	96	8.438	6.940	21.585	1.216	135.871	0.961
109	23/01/2014	14	125	Ap 0-5	136.372	49	6.121	4.334	41.232	1.412	96.559	0.683
110	23/01/2014	14	125	Ap 0-5	112.378	50	5.435	3.976	36.695	1.367	82.211	0.582
111	23/01/2014	14	125	Ap 0-5	146.173	51	7.049	5.214	35.194	1.352	108.121	0.765
112	23/01/2014	14	125	Ap 5-10	157.094	52	5.974	4.642	28.695	1.287	122.067	0.863
113	23/01/2014	14	125	Ap 5-10	164.641	53	6.001	4.618	29.948	1.299	126.698	0.896
114	23/01/2014	14	125	Ap 5-10	143.203	54	6.493	5.205	24.745	1.247	114.796	0.812
115	23/01/2014	14	125	Bw1 15-25	139.247	55	6.639	5.271	25.953	1.260	110.554	0.782
116	23/01/2014	14	125	Bw1 15-25	142.922	56	8.112	6.585	23.189	1.232	116.018	0.821
117	23/01/2014	14	125	Bw1 15-25	144.508	57	8.203	6.428	27.614	1.276	113.239	0.801
118	23/01/2014	14	125	Bw2 25-30	140.808	58	7.611	6.072	25.346	1.253	112.336	0.795
119	23/01/2014	14	125	Bw2 25-30	137.656	59	6.348	5.032	26.153	1.262	109.119	0.772
120	23/01/2014	14	125	Bw2 25-30	141.044	60	9.546	7.728	23.525	1.235	114.183	0.808
121	23/01/2014	11	A16	Ap 0-5	112.900	37	5.577	4.644	20.090	1.201	94.012	0.665
122	23/01/2014	11	A16	Ap 0-5	114.836	38	7.116	5.905	20.508	1.205	95.293	0.674
123	23/01/2014	11	A16	Ap 0-5	122.504	39	5.440	4.362	24.713	1.247	98.228	0.695
124	23/01/2014	11	A16	Ap 5-10	109.830	40	7.087	6.262	13.175	1.132	97.045	0.686
125	23/01/2014	11	A16	Ap 5-10	121.305	41	7.765	6.916	12.276	1.123	108.042	0.764
126	23/01/2014	11	A16	Ap 5-10	113.390	42	6.428	5.660	13.569	1.136	99.842	0.706
127	23/01/2014	11	A16	AB 10-20	114.050	43	6.008	5.474	9.755	1.098	103.913	0.735
128	23/01/2014	11	A16	AB 10-20	119.698	44	7.347	6.817	7.775	1.078	111.063	0.786
129	23/01/2014	11	A16	AB 10-20	106.263	45	5.404	4.936	9.481	1.095	97.060	0.687

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
130	23/01/2014	11	A16	Bw 20-30	123.257	46	6.638	6.061	9.520	1.095	112.543	0.796
131	23/01/2014	11	A16	Bw 20-30	120.637	47	6.080	5.427	12.032	1.120	107.680	0.762
132	23/01/2014	11	A16	Bw 20-30	125.004	48	6.507	5.868	10.890	1.109	112.728	0.797
133	22/01/2014	15	17	Ap 0-5	136.922	97	5.963	3.970	50.202	1.502	91.159	0.645
134	22/01/2014	15	17	Ap 0-5	138.747	98	6.149	4.100	49.976	1.500	92.513	0.654
135	22/01/2014	15	17	Ap 0-5	150.415	99	6.560	4.402	49.023	1.490	100.934	0.714
136	22/01/2014	15	17	Ap 5-10	154.793	100	6.980	4.747	47.040	1.470	105.273	0.745
137	22/01/2014	15	17	Ap 5-10	144.856	101	6.899	4.987	38.340	1.383	104.710	0.741
138	22/01/2014	15	17	Ap 5-10	150.392	102	7.571	5.249	44.237	1.442	104.267	0.738
139	22/01/2014	15	17	Bw 10-20	138.136	103	7.314	5.349	36.736	1.367	101.024	0.715
140	22/01/2014	15	17	Bw 10-20	143.336	104	7.394	5.323	38.907	1.389	103.189	0.730
141	22/01/2014	15	17	Bw 10-20	134.362	105	7.252	5.533	31.068	1.311	102.513	0.725
142	22/01/2014	15	17	bBw 20-30	131.880	106	7.927	5.889	34.607	1.346	97.974	0.693
143	22/01/2014	15	17	bBw 20-30	132.895	107	8.314	6.234	33.365	1.334	99.647	0.705
144	22/01/2014	15	17	bBw 20-30	134.396	108	6.278	4.694	33.745	1.337	100.487	0.711
145	24/01/2014	9	31B	Ap 0-5	134.396	13	5.200	4.009	29.708	1.297	103.614	0.733
146	24/01/2014	9	31B	Ap 0-5	112.572	14	5.298	4.170	27.050	1.271	88.604	0.627
147	24/01/2014	9	31B	Ap 0-5	107.692	15	5.353	4.194	27.635	1.276	84.375	0.597
148	24/01/2014	9	31B	Ap 5-10	103.080	16	5.548	4.605	20.478	1.205	85.559	0.605
149	24/01/2014	9	31B	Ap 5-10	114.238	17	6.000	4.999	20.024	1.200	95.179	0.673
150	24/01/2014	9	31B	Ap 5-10	107.951	18	5.546	4.654	19.166	1.192	90.589	0.641
151	24/01/2014	9	31B	Bw 15-25	106.853	19	6.329	5.497	15.136	1.151	92.806	0.656
152	24/01/2014	9	31B	Bw 15-25	96.049	20	6.376	5.552	14.841	1.148	83.636	0.592
153	24/01/2014	9	31B	Bw 15-25	98.158	21	5.631	4.856	15.960	1.160	84.648	0.599
154	24/01/2014	9	31B	Cu1 25-30	106.516	22	5.470	4.662	17.332	1.173	90.782	0.642
155	24/01/2014	9	31B	Cu1 25-30	107.781	23	6.641	5.578	19.057	1.191	90.529	0.640
156	24/01/2014	9	31B	Cu1 25-30	103.929	24	6.335	5.394	17.445	1.174	88.491	0.626
157	24/01/2014	9	33	Ap 0-5	125.042	10	5.505	3.896	41.299	1.413	88.495	0.626
158	24/01/2014	9	33	Ap 0-5	116.655	11	5.912	4.143	42.699	1.427	81.749	0.578
159	24/01/2014	9	33	Ap 0-5	116.191	12	6.434	4.380	46.895	1.469	79.098	0.560
160	24/01/2014	9	33	Ap 5-10	141.581	4	5.651	4.320	30.810	1.308	108.234	0.766
161	24/01/2014	9	33	Ap 5-10	135.550	5	5.568	4.068	36.873	1.369	99.033	0.701
162	24/01/2014	9	33	Ap 5-10	143.622	6	6.511	4.649	40.052	1.401	102.549	0.725
163	24/01/2014	9	33	Bw 15-25	124.594	7	6.701	5.378	24.600	1.246	99.995	0.707

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
164	24/01/2014	9	33	Bw 15-25	124.640	8	6.228	5.038	23.620	1.236	100.825	0.713
165	24/01/2014	9	33	Bw 15-25	127.562	9	6.225	5.041	23.487	1.235	103.300	0.731
166	24/01/2014	9	33	Cu1 25-30	130.555	1	5.829	4.477	30.199	1.302	100.274	0.709
167	24/01/2014	9	33	Cu1 25-30	115.930	2	5.631	4.481	25.664	1.257	92.254	0.653
168	24/01/2014	9	33	Cu1 25-30	123.186	3	6.270	4.932	27.129	1.271	96.898	0.685
169	24/01/2014	9	32A	Ap 0-5	132.239	25	5.821	4.560	27.654	1.277	103.592	0.733
170	24/01/2014	9	32A	Ap 0-5	125.502	26	5.672	4.442	27.690	1.277	98.286	0.695
171	24/01/2014	9	32A	Ap 0-5	122.197	27	5.993	4.576	30.966	1.310	93.304	0.660
172	24/01/2014	9	32A	Ap 5-10	129.099	28	7.021	5.799	21.073	1.211	106.629	0.754
173	24/01/2014	9	32A	Ap 5-10	126.063	29	5.907	4.784	23.474	1.235	102.097	0.722
174	24/01/2014	9	32A	Ap 5-10	121.747	30	6.236	5.042	23.681	1.237	98.436	0.696
175	24/01/2014	9	32A	Ap 10-20	123.990	31	6.251	5.089	22.834	1.228	100.941	0.714
176	24/01/2014	9	32A	Ap 10-20	118.016	32	5.651	4.335	30.358	1.304	90.533	0.640
177	24/01/2014	9	32A	Ap 10-20	126.065	33	6.317	4.950	27.616	1.276	98.785	0.699
178	24/01/2014	9	32A	Bw 20-25	121.025	34	6.733	5.756	16.974	1.170	103.464	0.732
179	24/01/2014	9	32A	Bw 20-25	119.232	35	6.116	5.082	20.346	1.203	99.074	0.701
180	24/01/2014	9	32A	Bw 20-25	122.734	36	6.254	5.226	19.671	1.197	102.560	0.725

Autumn

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
1	7/04/2014	15	8	Ap 0-5	124.920	73	5.848	4.818	21.378	1.21	102.918	0.728
2	7/04/2014	15	8	Ap 0-5	122.979	74	5.305	4.368	21.451	1.21	101.258	0.716
3	7/04/2014	15	8	Ap 0-5	125.465	75	5.354	4.457	20.126	1.20	104.445	0.739
4	7/04/2014	15	8	Ap 5-10	134.094	76	5.924	4.819	22.930	1.23	109.082	0.772
5	7/04/2014	15	8	Ap 5-10	128.359	77	5.734	4.645	23.445	1.23	103.981	0.736
6	7/04/2014	15	8	Ap 5-10	126.471	78	5.450	4.407	23.667	1.24	102.267	0.723
7	7/04/2014	15	8	Bw 10-20	134.730	79	5.371	4.365	23.047	1.23	109.495	0.775
8	7/04/2014	15	8	Bw 10-20	131.611	80	5.666	4.584	23.604	1.24	106.478	0.753
9	7/04/2014	15	8	Bw 10-20	133.543	81	5.797	4.677	23.947	1.24	107.742	0.762
10	7/04/2014	15	8	Bah 20-30	120.259	82	6.399	5.301	20.713	1.21	99.624	0.705
11	7/04/2014	15	8	Bah 20-30	120.323	83	5.648	4.605	22.649	1.23	98.103	0.694

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
12	7/04/2014	15	8	Bah 20-30	115.511	84	5.383	4.372	23.124	1.23	93.816	0.664
13	7/04/2014	15	15	Ap 0-5	118.882	85	5.119	4.566	12.111	1.12	106.039	0.750
14	7/04/2014	15	15	Ap 0-5	110.998	86	5.327	4.623	15.228	1.15	96.329	0.681
15	7/04/2014	15	15	Ap 0-5	107.420	87	5.991	5.363	11.710	1.12	96.160	0.680
16	7/04/2014	15	15	Ap 5-10	136.658	88	6.256	5.624	11.238	1.11	122.852	0.869
17	7/04/2014	15	15	Ap 5-10	126.114	89	5.257	4.692	12.042	1.12	112.560	0.796
18	7/04/2014	15	15	Ap 5-10	119.349	90	5.661	4.975	13.789	1.14	104.886	0.742
19	7/04/2014	15	15	Bw	124.966	91	8.074	7.334	10.090	1.10	113.513	0.803
20	7/04/2014	15	15	Bw	126.958	92	6.967	6.308	10.447	1.10	114.949	0.813
21	7/04/2014	15	15	Bw	122.769	93	6.654	6.028	10.385	1.10	111.219	0.787
22	7/04/2014	15	15	Cu1	110.073	94	6.030	5.220	15.517	1.16	95.287	0.674
23	7/04/2014	15	15	Cu1	94.139	95	5.448	4.855	12.214	1.12	83.892	0.593
24	7/04/2014	15	15	Cu1	97.290	96	5.025	4.303	16.779	1.17	83.311	0.589
25	7/04/2014	11	B12	Ap 0-5	112.432	97	5.986	5.491	9.015	1.09	103.135	0.730
26	7/04/2014	11	B12	Ap 0-5	119.620	98	6.570	6.021	9.118	1.09	109.624	0.775
27	7/04/2014	11	B12	Ap 0-5	128.581	99	7.386	6.743	9.536	1.10	117.387	0.830
28	7/04/2014	11	B12	Ap 5-10	123.912	100	5.671	5.232	8.391	1.08	114.320	0.809
29	7/04/2014	11	B12	Ap 5-10	132.208	101	6.148	5.705	7.765	1.08	122.682	0.868
30	7/04/2014	11	B12	Ap 5-10	129.317	102	6.352	5.863	8.340	1.08	119.362	0.844
31	7/04/2014	11	B12	Bw 10-20	134.700	103	9.085	8.589	5.775	1.06	127.346	0.901
32	7/04/2014	11	B12	Bw 10-20	125.005	104	6.604	6.194	6.619	1.07	117.244	0.829
33	7/04/2014	11	B12	Bw 10-20	138.299	105	8.078	7.726	4.556	1.05	132.273	0.936
34	7/04/2014	11	B12	Cu1 20-30	85.646	106	6.095	5.689	7.137	1.07	79.941	0.565
35	7/04/2014	11	B12	Cu1 20-30	89.320	107	8.795	8.310	5.836	1.06	84.394	0.597
36	7/04/2014	11	B12	Cu1 20-30	82.943	108	6.404	6.043	5.974	1.06	78.267	0.554
37	7/04/2014	15	37	Ap 0-5	125.869	109	5.930	5.028	17.940	1.18	106.723	0.755
38	7/04/2014	15	37	Ap 0-5	115.610	110	5.237	4.416	18.591	1.19	97.486	0.690
39	7/04/2014	15	37	Ap 0-5	119.065	111	5.645	4.736	19.193	1.19	99.892	0.707
40	7/04/2014	15	37	Ap 5-10	135.257	112	6.019	4.847	24.180	1.24	108.920	0.770
41	7/04/2014	15	37	Ap 5-10	151.331	113	5.915	4.571	29.403	1.29	116.946	0.827
42	7/04/2014	15	37	Ap 5-10	141.768	114	5.231	4.164	25.624	1.26	112.851	0.798
43	7/04/2014	15	37	Bw 10-20	127.722	115	6.627	5.253	26.156	1.26	101.241	0.716
44	7/04/2014	15	37	Bw 10-20	125.278	116	7.242	5.791	25.056	1.25	100.177	0.709
45	7/04/2014	15	37	Bw 10-20	125.059	117	6.325	5.082	24.459	1.24	100.482	0.711

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
46	7/04/2014	15	37	Bw 20-30	139.359	118	8.840	7.805	13.261	1.13	123.043	0.870
47	7/04/2014	15	37	Bw 20-30	140.356	119	7.990	6.860	16.472	1.16	120.506	0.852
48	7/04/2014	15	37	Bw 20-30	138.992	120	8.893	7.649	16.264	1.16	119.549	0.846
49	7/04/2014	15	35	Ap 0-5	112.089	121	5.619	4.879	15.167	1.15	97.327	0.688
50	7/04/2014	15	35	Ap 0-5	120.847	122	6.013	5.201	15.612	1.16	104.528	0.739
51	7/04/2014	15	35	Ap 0-5	119.138	123	5.597	4.864	15.070	1.15	103.535	0.732
52	7/04/2014	15	35	Ap 5-10	134.363	124	5.609	4.578	22.521	1.23	109.666	0.776
53	7/04/2014	15	35	Ap 5-10	131.073	125	5.999	4.986	20.317	1.20	108.940	0.771
54	7/04/2014	15	35	Ap 5-10	132.394	126	6.379	5.447	17.110	1.17	113.051	0.800
55	7/04/2014	15	35	Bw 10-20	119.579	127	5.462	4.813	13.484	1.13	105.371	0.745
56	7/04/2014	15	35	Bw 10-20	123.035	128	5.881	5.231	12.426	1.12	109.437	0.774
57	7/04/2014	15	35	Bw 10-20	122.025	129	5.122	4.336	18.127	1.18	103.300	0.731
58	7/04/2014	15	35	Cu 20-30	115.554	130	5.970	5.349	11.610	1.12	103.534	0.732
59	7/04/2014	15	35	Cu 20-30	119.206	131	5.577	5.003	11.473	1.11	106.937	0.756
60	7/04/2014	15	35	Cu 20-30	119.240	132	5.251	4.642	13.119	1.13	105.411	0.746
61	8/04/2014	14	147	Ap 0-5	112.698	97	5.376	5.069	6.056	1.06	106.262	0.752
62	8/04/2014	14	147	Ap 0-5	107.179	98	5.649	5.376	5.078	1.05	101.999	0.721
63	8/04/2014	14	147	Ap 0-5	117.035	99	5.771	5.383	7.208	1.07	109.166	0.772
64	8/04/2014	14	147	Ap 5-10	128.563	100	6.206	5.732	8.269	1.08	118.744	0.840
65	8/04/2014	14	147	Ap 5-10	127.141	101	6.078	5.588	8.769	1.09	116.891	0.827
66	8/04/2014	14	147	Ap 5-10	127.258	102	5.489	5.082	8.009	1.08	117.822	0.833
67	8/04/2014	14	147	Ap 10-20	143.971	103	7.520	6.891	9.128	1.09	131.929	0.933
68	8/04/2014	14	147	Ap 10-20	141.620	104	6.581	5.902	11.505	1.12	127.008	0.898
69	8/04/2014	14	147	Ap 10-20	161.283	105	7.077	6.378	10.960	1.11	145.353	1.028
70	8/04/2014	14	147	Bw 22-30	139.313	106	6.759	6.043	11.848	1.12	124.555	0.881
71	8/04/2014	14	147	Bw 22-30	144.691	107	6.076	5.248	15.777	1.16	124.973	0.884
72	8/04/2014	14	147	Bw 22-30	148.677	108	6.150	5.397	13.952	1.14	130.473	0.923
73	8/04/2014	14	149	Ap 0-5	115.393	109	5.621	4.908	14.527	1.15	100.756	0.713
74	8/04/2014	14	149	Ap 0-5	120.960	110	5.375	4.707	14.192	1.14	105.927	0.749
75	8/04/2014	14	149	Ap 0-5	112.592	111	5.113	4.420	15.679	1.16	97.332	0.688
76	8/04/2014	14	149	Ap 5-10	124.640	112	5.419	4.787	13.202	1.13	110.104	0.779
77	8/04/2014	14	149	Ap 5-10	129.297	113	6.147	5.511	11.541	1.12	115.919	0.820
78	8/04/2014	14	149	Ap 5-10	125.734	114	6.329	5.689	11.250	1.11	113.020	0.799
79	8/04/2014	14	149	Bw 10-22	126.680	115	5.662	5.226	8.343	1.08	116.925	0.827

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
80	8/04/2014	14	149	Bw 10-22	122.773	116	6.156	5.713	7.754	1.08	113.938	0.806
81	8/04/2014	14	149	Bw 10-22	121.418	117	6.170	5.726	7.754	1.08	112.681	0.797
82	8/04/2014	14	149	Cu 22- 30	100.041	118	7.956	7.267	9.481	1.09	91.377	0.646
83	8/04/2014	14	149	Cu 22- 30	106.738	119	6.680	6.082	9.832	1.10	97.183	0.687
84	8/04/2014	14	149	Cu 22- 30	119.745	120	8.113	7.576	7.088	1.07	111.819	0.791
85	8/04/2014	14	146	Ap 0-5	115.534	121	5.203	4.858	7.102	1.07	107.873	0.763
86	8/04/2014	14	146	Ap 0-5	128.138	122	7.208	6.849	5.242	1.05	121.756	0.861
87	8/04/2014	14	146	Ap 0-5	128.019	123	6.565	6.210	5.717	1.06	121.096	0.857
88	8/04/2014	14	146	Ap 5-10	139.792	124	6.777	6.469	4.761	1.05	133.439	0.944
89	8/04/2014	14	146	Ap 5-10	142.642	125	5.037	4.825	4.394	1.04	136.638	0.967
90	8/04/2014	14	146	Ap 5-10	142.264	126	5.698	5.523	3.169	1.03	137.895	0.975
91	8/04/2014	14	146	Ap2 10-15	132.405	127	5.175	4.933	4.906	1.05	126.213	0.893
92	8/04/2014	14	146	Ap2 10-15	142.699	128	6.366	6.119	4.037	1.04	137.162	0.970
93	8/04/2014	14	146	Ap2 10-15	136.602	129	6.290	6.024	4.416	1.04	130.825	0.925
94	8/04/2014	14	146	Bw 15-28	121.974	130	7.198	6.577	9.442	1.09	111.451	0.788
95	8/04/2014	14	146	Bw 15-28	112.148	131	5.812	5.479	6.078	1.06	105.722	0.748
96	8/04/2014	14	146	Bw 15-28	117.029	132	5.260	4.958	6.091	1.06	110.310	0.780
97	8/04/2014	14	148	Ap 0-5	117.992	133	5.625	5.030	11.829	1.12	105.511	0.746
98	8/04/2014	14	148	Ap 0-5	114.659	134	5.797	5.182	11.868	1.12	102.495	0.725
99	8/04/2014	14	148	Ap 0-5	129.177	135	5.238	4.653	12.573	1.13	114.750	0.812
100	8/04/2014	14	148	Ap 5-10	113.714	136	5.957	5.313	12.121	1.12	101.421	0.717
101	8/04/2014	14	148	Ap 5-10	124.121	137	6.357	5.674	12.037	1.12	110.785	0.784
102	8/04/2014	14	148	Ap 5-10	124.039	138	5.090	4.541	12.090	1.12	110.660	0.783
103	8/04/2014	14	148	Bw1 10-20	109.610	139	5.840	5.320	9.774	1.10	99.850	0.706
104	8/04/2014	14	148	Bw1 10-20	112.759	140	5.679	4.901	15.874	1.16	97.311	0.688
105	8/04/2014	14	148	Bw1 10-20	118.297	141	6.341	5.675	11.736	1.12	105.872	0.749
106	8/04/2014	14	148	Bw2 20-30	118.751	142	7.434	6.939	7.134	1.07	110.844	0.784
107	8/04/2014	14	148	Bw2 20-30	128.375	143	7.326	6.833	7.215	1.07	119.736	0.847
108	8/04/2014	14	148	Bw2 20-30	128.358	144	6.043	5.632	7.298	1.07	119.628	0.846
109	8/04/2014	14	125	Ap 0-5	115.029	145	6.387	5.805	10.026	1.10	104.547	0.740
110	8/04/2014	14	125	Ap 0-5	114.349	146	5.779	5.208	10.964	1.11	103.051	0.729
111	8/04/2014	14	125	Ap 0-5	130.613	147	5.824	5.340	9.064	1.09	119.758	0.847
112	8/04/2014	14	125	Ap 5-10	138.152	148	8.486	7.729	9.794	1.10	125.828	0.890
113	8/04/2014	14	125	Ap 5-10	134.453	149	5.230	4.723	10.735	1.11	121.419	0.859

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
114	8/04/2014	14	125	Ap 5-10	129.626	150	5.695	5.196	9.604	1.10	118.268	0.837
115	8/04/2014	14	125	Bw1 15-25	131.025	151	6.662	6.097	9.267	1.09	119.913	0.848
116	8/04/2014	14	125	Bw1 15-25	132.713	152	5.743	5.292	8.522	1.09	122.291	0.865
117	8/04/2014	14	125	Bw1 15-25	138.570	153	8.397	7.746	8.404	1.08	127.827	0.904
118	8/04/2014	14	125	Bw2 25-30	123.203	154	6.961	6.489	7.274	1.07	114.849	0.812
119	8/04/2014	14	125	Bw2 25-30	114.775	155	7.057	6.523	8.186	1.08	106.090	0.750
120	8/04/2014	14	125	Bw2 25-30	128.436	156	7.590	7.054	7.599	1.08	119.366	0.844
121	7/04/2014	11	A16	Ap 0-5	132.235	145	8.137	7.515	8.277	1.08	122.127	0.864
122	7/04/2014	11	A16	Ap 0-5	130.217	146	9.817	9.017	8.872	1.09	119.605	0.846
123	7/04/2014	11	A16	Ap 0-5	128.479	147	9.842	9.243	6.481	1.06	120.660	0.853
124	7/04/2014	11	A16	Ap 5-10	123.995	148	7.979	7.153	11.548	1.12	111.159	0.786
125	7/04/2014	11	A16	Ap 5-10	127.107	149	7.617	6.898	10.423	1.10	115.109	0.814
126	7/04/2014	11	A16	Ap 5-10	133.436	150	5.626	5.093	10.465	1.10	120.794	0.854
127	7/04/2014	11	A16	AB 10-20	128.452	151	5.690	5.120	11.133	1.11	115.584	0.818
128	7/04/2014	11	A16	AB 10-20	119.687	152	6.221	5.757	8.060	1.08	110.760	0.783
129	7/04/2014	11	A16	AB 10-20	122.204	153	6.423	5.953	7.895	1.08	113.262	0.801
130	7/04/2014	11	A16	Bw 20-30	111.631	154	7.871	6.826	15.309	1.15	96.810	0.685
131	7/04/2014	11	A16	Bw 20-30	124.114	155	8.896	7.765	14.565	1.15	108.335	0.766
132	7/04/2014	11	A16	Bw 20-30	117.219	156	9.608	8.293	15.857	1.16	101.176	0.716
133	8/04/2014	15	17	Ap 0-5	124.172	133	5.545	4.495	23.359	1.23	100.659	0.712
134	8/04/2014	15	17	Ap 0-5	125.024	134	6.025	4.811	25.234	1.25	99.832	0.706
135	8/04/2014	15	17	Ap 0-5	127.306	135	5.874	5.047	16.386	1.16	109.383	0.774
136	8/04/2014	15	17	Ap 5-10	124.595	136	5.162	4.535	13.826	1.14	109.461	0.774
137	8/04/2014	15	17	Ap 5-10	123.341	137	5.882	4.854	21.178	1.21	101.785	0.720
138	8/04/2014	15	17	Ap 5-10	124.585	138	5.082	4.358	16.613	1.17	106.836	0.756
139	8/04/2014	15	17	Bw 10-20	120.331	139	7.004	5.807	20.613	1.21	99.766	0.706
140	8/04/2014	15	17	Bw 10-20	121.871	140	6.002	4.890	22.740	1.23	99.292	0.702
141	8/04/2014	15	17	Bw 10-20	119.942	141	6.314	5.132	23.032	1.23	97.488	0.690
142	8/04/2014	15	17	Bbw 20-30	127.989	142	6.809	5.559	22.486	1.22	104.493	0.739
143	8/04/2014	15	17	Bbw 20-30	125.504	143	9.128	7.623	19.743	1.20	104.811	0.741
144	8/04/2014	15	17	Bbw 20-30	122.417	144	6.603	5.393	22.436	1.22	99.984	0.707
145	8/04/2014	9	31B	Ap 0-5	105.924	157	5.294	4.690	12.878	1.13	93.839	0.664
146	8/04/2014	9	31B	Ap 0-5	102.009	158	5.311	4.766	11.435	1.11	91.541	0.648
147	8/04/2014	9	31B	Ap 0-5	107.943	159	5.882	5.252	11.995	1.12	96.382	0.682

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
148	8/04/2014	9	31B	Ap 5-10	106.780	160	5.609	4.921	13.981	1.14	93.682	0.663
149	8/04/2014	9	31B	Ap 5-10	106.333	161	5.439	4.741	14.723	1.15	92.687	0.656
150	8/04/2014	9	31B	Ap 5-10	104.832	162	5.748	4.938	16.403	1.16	90.059	0.637
151	8/04/2014	9	31B	Bw 15-25	93.529	163	5.911	5.150	14.777	1.15	81.488	0.576
152	8/04/2014	9	31B	Bw 15-25	95.878	164	5.766	5.110	12.838	1.13	84.970	0.601
153	8/04/2014	9	31B	Bw 15-25	94.210	165	5.689	4.096	38.892	1.39	67.830	0.480
154	8/04/2014	9	31B	Cu1 25-30	90.205	166	5.571	5.794	-3.849	0.96	93.816	0.664
155	8/04/2014	9	31B	Cu1 25-30	91.703	167	5.583	5.142	8.576	1.09	84.459	0.597
156	8/04/2014	9	31B	Cu1 25-30	91.585	168	6.644	6.080	9.276	1.09	83.810	0.593
157	8/04/2014	9	33	Ap 0-5	102.286	73	5.365	4.758	12.757	1.13	90.713	0.642
158	8/04/2014	9	33	Ap 0-5	90.092	74	5.345	4.711	13.458	1.13	79.406	0.562
159	8/04/2014	9	33	Ap 0-5	110.105	75	5.410	4.819	12.264	1.12	98.077	0.694
160	8/04/2014	9	33	Ap 5-10	112.105	76	5.313	4.717	12.635	1.13	99.529	0.704
161	8/04/2014	9	33	Ap 5-10	114.552	77	5.543	4.921	12.640	1.13	101.698	0.719
162	8/04/2014	9	33	Ap 5-10	110.726	78	5.965	5.300	12.547	1.13	98.382	0.696
163	8/04/2014	9	33	Bw 15-25	112.362	79	6.283	5.576	12.679	1.13	99.718	0.705
164	8/04/2014	9	33	Bw 15-25	105.822	80	5.564	4.936	12.723	1.13	93.878	0.664
165	8/04/2014	9	33	Bw 15-25	119.725	81	5.462	4.909	11.265	1.11	107.603	0.761
166	8/04/2014	9	33	Cu1 25-35	100.130	82	5.882	5.506	6.829	1.07	93.729	0.663
167	8/04/2014	9	33	Cu1 25-35	105.336	83	5.385	5.042	6.803	1.07	98.627	0.698
168	8/04/2014	9	33	Cu1 25-35	105.266	84	5.275	4.965	6.244	1.06	99.080	0.701
169	8/04/2014	9	32A	Ap 0-5	119.529	85	5.690	4.996	13.891	1.14	104.950	0.742
170	8/04/2014	9	32A	Ap 0-5	125.249	86	6.009	5.330	12.739	1.13	111.096	0.786
171	8/04/2014	9	32A	Ap 0-5	112.054	87	5.569	5.131	8.536	1.09	103.241	0.730
172	8/04/2014	9	32A	Ap 5-10	119.985	88	5.351	4.700	13.851	1.14	105.388	0.745
173	8/04/2014	9	32A	Ap 5-10	110.556	89	5.427	4.791	13.275	1.13	97.600	0.690
174	8/04/2014	9	32A	Ap 5-10	112.268	90	5.213	4.553	14.496	1.14	98.054	0.694
175	8/04/2014	9	32A	Ap 10-20	111.502	91	5.021	4.468	12.377	1.12	99.221	0.702
176	8/04/2014	9	32A	Ap 10-20	108.093	92	5.779	5.136	12.519	1.13	96.066	0.680
177	8/04/2014	9	32A	Ap 10-20	105.046	93	5.331	4.840	10.145	1.10	95.371	0.675
178	8/04/2014	9	32A	Bw 20-25	101.062	94	5.227	4.788	9.169	1.09	92.574	0.655
179	8/04/2014	9	32A	Bw 20-25	91.958	95	5.015	4.639	8.105	1.08	85.063	0.602
180	8/04/2014	9	32A	Bw 20-25	102.059	96	5.394	4.965	8.640	1.09	93.942	0.665

Winter

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg $Cm^{-3)}$
1	14/07/2014	15	8	Ap 0-5	181.090	13	5.091	3.069	65.885	1.66	109.166	0.772
2	14/07/2014	15	8	Ap 0-5	166.110	14	5.536	3.258	69.920	1.70	97.758	0.691
3	14/07/2014	15	8	Ap 0-5	168.310	15	5.867	3.526	66.393	1.66	101.152	0.716
4	14/07/2014	15	8	Ap 5-10	177.120	16	6.746	4.524	49.116	1.49	118.780	0.840
5	14/07/2014	15	8	Ap 5-10	162.580	17	5.618	3.641	54.298	1.54	105.367	0.745
6	14/07/2014	15	8	Ap 5-10	178.450	18	5.621	3.711	51.469	1.51	117.813	0.833
7	14/07/2014	15	8	Bw 10-20	163.020	19	7.347	4.845	51.641	1.52	107.504	0.760
8	14/07/2014	15	8	Bw 10-20	159.370	20	7.284	4.666	56.108	1.56	102.090	0.722
9	14/07/2014	15	8	Bw 10-20	162.840	21	6.403	4.085	56.744	1.57	103.889	0.735
10	14/07/2014	15	8	Cu 20-30	149.000	22	7.599	5.812	30.747	1.31	113.961	0.806
11	14/07/2014	15	8	Cu 20-30	154.080	23	7.716	6.214	24.171	1.24	124.087	0.878
12	14/07/2014	15	8	Cu 20-30	158.190	24	8.225	6.727	22.268	1.22	129.379	0.915
13	14/07/2014	15	15	Ap 0-5	150.420	25	6.581	4.215	56.133	1.56	96.341	0.681
14	14/07/2014	15	15	Ap 0-5	172.330	26	7.237	4.505	60.644	1.61	107.275	0.759
15	14/07/2014	15	15	Ap 0-5	154.520	27	5.748	3.649	57.523	1.58	98.094	0.694
16	14/07/2014	15	15	Ap 5-10	178.140	28	6.110	4.296	42.225	1.42	125.252	0.886
17	14/07/2014	15	15	Ap 5-10	176.930	29	6.732	4.821	39.639	1.40	126.705	0.896
18	14/07/2014	15	15	Ap 5-10	174.110	30	6.263	4.106	52.533	1.53	114.146	0.807
19	14/07/2014	15	15	Bw 10-20	170.640	31	6.811	5.085	33.943	1.34	127.398	0.901
20	14/07/2014	15	15	Bw 10-20	182.580	32	7.254	5.490	32.131	1.32	138.181	0.977
21	14/07/2014	15	15	Bw 10-20	184.360	33	8.827	7.422	18.930	1.19	155.015	1.097
22	14/07/2014	15	15	Cu1 20-30	119.950	34	6.757	4.305	56.957	1.57	76.422	0.541
23	14/07/2014	15	15	Cu1 20-30	130.460	35	7.558	4.792	57.721	1.58	82.716	0.585
24	14/07/2014	15	15	Cu1 20-30	138.420	36	7.919	5.413	46.296	1.46	94.616	0.669
25	14/07/2014	11	B12	Ap 0-5	176.380	133	8.641	5.469	58.000	1.58	111.633	0.790
26	14/07/2014	11	B12	Ap 0-5	170.900	134	8.478	5.443	55.760	1.56	109.720	0.776
27	14/07/2014	11	B12	Ap 0-5	172.070	135	11.321	7.070	60.127	1.60	107.458	0.760
28	14/07/2014	11	B12	Ap 5-10	168.500	136	10.274	6.681	53.779	1.54	109.573	0.775
29	14/07/2014	11	B12	Ap 5-10	171.410	137	8.578	5.724	49.860	1.50	114.380	0.809
30	14/07/2014	11	B12	Ap 5-10	174.090	138	7.986	5.200	53.577	1.54	113.357	0.802
31	14/07/2014	11	B12	AB 10-20	157.620	139	8.609	5.827	47.743	1.48	106.685	0.755
32	14/07/2014	11	B12	AB 10-20	165.760	140	9.426	6.320	49.146	1.49	111.140	0.786

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
33	14/07/2014	11	B12	AB 10-20	161.250	141	10.019	6.771	47.969	1.48	108.975	0.771
34	14/07/2014	11	B12	Bw 20-30	140.510	142	7.088	4.702	50.744	1.51	93.211	0.659
35	14/07/2014	11	B12	Bw 20-30	156.590	143	11.762	7.576	55.253	1.55	100.861	0.713
36	14/07/2014	11	B12	Bw 20-30	143.150	144	7.965	5.312	49.944	1.50	95.469	0.675
37	15/07/2014	15	37	Ap 0-5	116.080	37	5.104	3.137	62.703	1.63	71.345	0.505
38	15/07/2014	15	37	Ap 0-5	130.430	38	6.024	3.848	56.549	1.57	83.316	0.589
39	15/07/2014	15	37	Ap 0-5	127.860	39	5.487	3.318	65.371	1.65	77.317	0.547
40	15/07/2014	15	37	Ap 5-10	173.370	40	6.215	4.070	52.703	1.53	113.534	0.803
41	15/07/2014	15	37	Ap 5-10	157.890	41	6.269	4.130	51.792	1.52	104.017	0.736
42	15/07/2014	15	37	Ap 5-10	155.470	42	6.291	4.108	53.140	1.53	101.521	0.718
43	15/07/2014	15	37	Bw 10-20	154.070	43	6.092	4.002	52.224	1.52	101.213	0.716
44	15/07/2014	15	37	Bw 10-20	169.280	44	8.786	5.793	51.666	1.52	111.614	0.790
45	15/07/2014	15	37	Bw 10-20	163.640	45	7.504	4.951	51.565	1.52	107.967	0.764
46	15/07/2014	15	37	Cu 20-30	140.080	46	6.280	4.259	47.452	1.47	95.000	0.672
47	15/07/2014	15	37	Cu 20-30	144.740	47	7.106	4.798	48.103	1.48	97.729	0.691
48	15/07/2014	15	37	Cu 20-30	146.950	48	8.080	5.534	46.007	1.46	100.646	0.712
49	14/07/2014	15	35	Ap 0-5	181.750	49	7.426	4.229	75.597	1.76	103.504	0.732
50	14/07/2014	15	35	Ap 0-5	177.030	50	6.775	4.142	63.568	1.64	108.230	0.766
51	14/07/2014	15	35	Ap 0-5	182.360	51	6.989	4.347	60.778	1.61	113.424	0.802
52	14/07/2014	15	35	Ap 5-10	178.070	52	6.576	4.191	56.908	1.57	113.487	0.803
53	14/07/2014	15	35	Ap 5-10	184.970	53	6.604	4.182	57.915	1.58	117.133	0.829
54	14/07/2014	15	35	Ap 5-10	172.470	54	8.901	5.594	59.117	1.59	108.392	0.767
55	14/07/2014	15	35	Bw 10-20	165.950	55	6.745	4.305	56.678	1.57	105.918	0.749
56	14/07/2014	15	35	Bw 10-20	173.320	56	8.094	5.127	57.870	1.58	109.786	0.777
57	14/07/2014	15	35	Bw 10-20	172.430	57	6.907	4.438	55.633	1.56	110.793	0.784
58	14/07/2014	15	35	Cu 20-30	166.010	58	9.521	6.475	47.042	1.47	112.899	0.799
59	14/07/2014	15	35	Cu 20-30	176.220	59	8.272	5.678	45.685	1.46	120.960	0.856
60	14/07/2014	15	35	Cu 20-30	173.320	60	9.576	6.067	57.837	1.58	109.809	0.777
61	15/07/2014	14	147	Ap 0-5	165.060	73	11.500	7.195	59.833	1.60	103.270	0.730
62	15/07/2014	14	147	Ap 0-5	169.110	74	8.311	4.840	71.715	1.72	98.483	0.697
63	15/07/2014	14	147	Ap 0-5	166.960	75	8.490	5.286	60.613	1.61	103.952	0.735
64	15/07/2014	14	147	Ap 5-10	156.520	76	9.334	5.965	56.479	1.56	100.026	0.708
65	15/07/2014	14	147	Ap 5-10	160.820	77	11.118	7.013	58.534	1.59	101.442	0.718
66	15/07/2014	14	147	Ap 5-10	156.110	78	8.982	5.524	62.600	1.63	96.009	0.679

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
67	15/07/2014	14	147	Bw1 10-20	146.890	79	7.398	3.934	88.053	1.88	78.111	0.553
68	15/07/2014	14	147	Bw1 10-20	171.560	80	10.340	6.138	68.459	1.68	101.841	0.720
69	15/07/2014	14	147	Bw1 10-20	155.800	81	11.037	6.218	77.501	1.78	87.774	0.621
70	15/07/2014	14	147	Bw2 22-30	162.020	82	9.195	5.839	57.476	1.57	102.886	0.728
71	15/07/2014	14	147	Bw2 22-30	153.250	83	9.955	6.178	61.136	1.61	95.106	0.673
72	15/07/2014	14	147	Bw2 22-30	153.090	84	10.797	6.557	64.664	1.65	92.971	0.658
73	15/07/2014	14	149	Ap 0-5	154.930	85	7.688	4.840	58.843	1.59	97.537	0.690
74	15/07/2014	14	149	Ap 0-5	141.350	86	7.319	4.455	64.287	1.64	86.038	0.609
75	15/07/2014	14	149	Ap 0-5	122.540	87	6.762	3.975	70.113	1.70	72.034	0.510
76	15/07/2014	14	149	Ap 5-10	149.220	88	8.862	5.515	60.689	1.61	92.863	0.657
77	15/07/2014	14	149	Ap 5-10	147.520	89	5.698	3.764	51.382	1.51	97.449	0.689
78	15/07/2014	14	149	Ap 5-10	141.140	90	7.200	4.670	54.176	1.54	91.545	0.648
79	15/07/2014	14	149	Bw 10-22	145.320	91	7.193	4.715	52.556	1.53	95.257	0.674
80	15/07/2014	14	149	Bw 10-22	151.160	92	7.245	4.745	52.687	1.53	99.000	0.700
81	15/07/2014	14	149	Bw 10-22	153.280	93	8.027	5.291	51.710	1.52	101.035	0.715
82	15/07/2014	14	149	Cu 22- 30	146.570	94	8.072	5.288	52.648	1.53	96.019	0.679
83	15/07/2014	14	149	Cu 22- 30	152.680	95	7.193	4.710	52.718	1.53	99.975	0.707
84	15/07/2014	14	149	Cu 22- 30	149.430	96	9.581	6.282	52.515	1.53	97.977	0.693
85	15/07/2014	14	146	Ap1 0-5	162.070	97	7.274	4.804	51.415	1.51	107.037	0.757
86	15/07/2014	14	146	Ap1 0-5	157.300	98	7.817	5.234	49.350	1.49	105.323	0.745
87	15/07/2014	14	146	Ap1 0-5	170.770	99	8.373	5.537	51.219	1.51	112.929	0.799
88	15/07/2014	14	146	Ap1 5-10	174.770	100	8.626	5.970	44.489	1.44	120.957	0.856
89	15/07/2014	14	146	Ap1 5-10	176.110	101	9.409	6.386	47.338	1.47	119.528	0.845
90	15/07/2014	14	146	Ap1 5-10	173.760	102	11.370	7.903	43.869	1.44	120.776	0.854
91	15/07/2014	14	146	Ap2 10-20	170.250	103	8.253	5.552	48.649	1.49	114.531	0.810
92	15/07/2014	14	146	Ap2 10-20	174.240	104	10.358	7.007	47.824	1.48	117.870	0.834
93	15/07/2014	14	146	Ap2 10-20	174.890	105	9.309	6.787	37.159	1.37	127.509	0.902
94	15/07/2014	14	146	Bw 20-30	165.180	106	11.025	8.815	25.071	1.25	132.069	0.934
95	15/07/2014	14	146	Bw 20-30	161.050	107	11.551	9.945	16.149	1.16	138.658	0.981
96	15/07/2014	14	146	Bw 20-30	171.240	108	10.249	8.358	22.625	1.23	139.645	0.988
97	15/07/2014	14	148	Ap 0-5	167.320	109	8.796	5.626	56.346	1.56	107.019	0.757
98	15/07/2014	14	148	Ap 0-5	147.720	110	7.746	5.136	50.818	1.51	97.946	0.693
99	15/07/2014	14	148	Ap 0-5	153.020	111	8.850	5.576	58.716	1.59	96.411	0.682
100	15/07/2014	14	148	Ap 5-10	154.740	112	8.783	5.837	50.471	1.50	102.837	0.727

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
101	15/07/2014	14	148	Ap 5-10	158.770	113	7.164	4.657	53.833	1.54	103.209	0.730
102	15/07/2014	14	148	Ap 5-10	163.270	114	6.911	4.268	61.926	1.62	100.830	0.713
103	15/07/2014	14	148	Bw1 10-20	146.620	115	7.673	5.064	51.521	1.52	96.766	0.684
104	15/07/2014	14	148	Bw1 10-20	156.060	116	7.632	5.086	50.059	1.50	103.999	0.736
105	15/07/2014	14	148	Bw1 10-20	150.010	117	9.641	6.410	50.406	1.50	99.737	0.705
106	15/07/2014	14	148	Bw2 20-30	155.840	118	11.519	7.633	50.911	1.51	103.266	0.730
107	15/07/2014	14	148	Bw2 20-30	155.280	119	10.468	6.827	53.332	1.53	101.270	0.716
108	15/07/2014	14	148	Bw2 20-30	160.340	120	8.893	5.876	51.344	1.51	105.944	0.749
109	15/07/2014	14	125	Ap 0-5	180.190	121	11.564	7.596	52.238	1.52	118.361	0.837
110	15/07/2014	14	125	Ap 0-5	170.410	122	10.122	6.689	51.323	1.51	112.613	0.797
111	15/07/2014	14	125	Ap 0-5	162.400	123	7.126	4.662	52.853	1.53	106.246	0.752
112	15/07/2014	14	125	Ap 5-10	171.650	124	9.169	6.129	49.600	1.50	114.739	0.812
113	15/07/2014	14	125	Ap 5-10	179.840	125	7.852	5.231	50.105	1.50	119.809	0.847
114	15/07/2014	14	125	Ap 5-10	172.890	126	10.676	7.088	50.621	1.51	114.785	0.812
115	15/07/2014	14	125	Bw1 15-25	169.370	127	8.434	5.646	49.380	1.49	113.382	0.802
116	15/07/2014	14	125	Bw1 15-25	169.390	128	8.259	5.642	46.384	1.46	115.716	0.819
117	15/07/2014	14	125	Bw1 15-25	172.340	129	9.740	6.460	50.774	1.51	114.304	0.809
118	15/07/2014	14	125	Bw2 25-30	158.790	130	9.140	6.461	41.464	1.41	112.248	0.794
119	15/07/2014	14	125	Bw2 25-30	167.120	131	8.049	5.705	41.087	1.41	118.452	0.838
120	15/07/2014	14	125	Bw2 25-30	174.240	132	8.263	5.946	38.967	1.39	125.382	0.887
121	14/07/2014	11	A16	Ap 0-5	166.780	145	8.889	5.270	68.672	1.69	98.878	0.699
122	14/07/2014	11	A16	Ap 0-5	176.060	146	9.744	5.773	68.786	1.69	104.310	0.738
123	14/07/2014	11	A16	Ap 0-5	178.140	147	9.617	5.603	71.640	1.72	103.787	0.734
124	14/07/2014	11	A16	Ap 5-10	161.580	148	9.332	5.828	60.124	1.60	100.910	0.714
125	14/07/2014	11	A16	Ap 5-10	176.480	149	9.607	5.982	60.598	1.61	109.889	0.777
126	14/07/2014	11	A16	Ap 5-10	175.980	150	8.661	5.851	48.026	1.48	118.885	0.841
127	14/07/2014	11	A16	AB 10-20	172.880	151	11.157	8.002	39.428	1.39	123.993	0.877
128	14/07/2014	11	A16	AB 10-20	172.350	152	10.183	7.091	43.605	1.44	120.017	0.849
129	14/07/2014	11	A16	AB 10-20	178.110	153	10.589	7.461	41.925	1.42	125.496	0.888
130	14/07/2014	11	A16	Bw 20-30	156.900	154	9.937	6.417	54.854	1.55	101.321	0.717
131	14/07/2014	11	A16	Bw 20-30	157.580	155	8.998	5.884	52.923	1.53	103.045	0.729
132	14/07/2014	11	A16	Bw 20-30	166.780	156	10.122	6.614	53.039	1.53	108.979	0.771
133	14/07/2014	15	17	Ap 0-5	171.670	61	8.822	5.317	65.921	1.66	103.465	0.732
134	14/07/2014	15	17	Ap 0-5	156.090	62	7.655	4.597	66.522	1.67	93.736	0.663

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
135	14/07/2014	15	17	Ap 0-5	175.220	63	7.722	4.612	67.433	1.67	104.651	0.740
136	14/07/2014	15	17	Ap 5-10	167.230	64	8.197	4.865	68.489	1.68	99.253	0.702
137	14/07/2014	15	17	Ap 5-10	169.070	65	7.015	4.058	72.868	1.73	97.803	0.692
138	14/07/2014	15	17	Ap 5-10	176.840	66	10.989	6.832	60.846	1.61	109.944	0.778
139	14/07/2014	15	17	bAh 10-20	157.740	67	9.277	5.364	72.949	1.73	91.206	0.645
140	14/07/2014	15	17	bAh 10-20	154.820	68	8.550	5.120	66.992	1.67	92.711	0.656
141	14/07/2014	15	17	bAh 10-20	159.250	69	11.058	6.618	67.090	1.67	95.308	0.674
142	14/07/2014	15	17	Cu 20-30	154.850	70	9.156	5.584	63.968	1.64	94.439	0.668
143	14/07/2014	15	17	Cu 20-30	147.730	71	9.125	5.861	55.690	1.56	94.887	0.671
144	14/07/2014	15	17	Cu 20-30	145.700	72	9.428	5.700	65.404	1.65	88.088	0.623
145	15/07/2014	9	31B	Ap 0-5	161.340	1	5.943	3.241	83.369	1.83	87.986	0.622
146	15/07/2014	9	31B	Ap 0-5	166.160	2	6.617	3.680	79.810	1.80	92.409	0.654
147	15/07/2014	9	31B	Ap 0-5	157.720	3	5.273	2.941	79.293	1.79	87.968	0.622
148	15/07/2014	9	31B	Ap 5-10	146.680	4	6.143	3.810	61.234	1.61	90.974	0.644
149	15/07/2014	9	31B	Ap 5-10	141.610	5	5.806	3.602	61.188	1.61	87.854	0.621
150	15/07/2014	9	31B	Ap 5-10	134.990	6	5.087	3.154	61.287	1.61	83.695	0.592
151	15/07/2014	9	31B	Bw 15-25	144.490	7	6.568	4.191	56.717	1.57	92.198	0.652
152	15/07/2014	9	31B	Bw 15-25	143.770	8	6.089	3.985	52.798	1.53	94.092	0.666
153	15/07/2014	9	31B	Bw 15-25	136.890	9	6.302	4.110	53.333	1.53	89.276	0.631
154	15/07/2014	9	31B	Cu1 25-30	131.730	10	6.078	4.307	41.119	1.41	93.347	0.660
155	15/07/2014	9	31B	Cu1 25-30	130.860	11	5.575	3.944	41.354	1.41	92.576	0.655
156	15/07/2014	9	31B	Cu1 25-30	125.600	12	6.431	4.509	42.626	1.43	88.063	0.623
157	16/07/2014	9	33	Ap 0-5	185.420	13	9.413	5.400	74.315	1.74	106.371	0.752
158	16/07/2014	9	33	Ap 0-5	183.310	14	7.892	4.385	79.977	1.80	101.852	0.720
159	16/07/2014	9	33	Ap 0-5	189.460	15	7.144	3.910	82.711	1.83	103.694	0.733
160	16/07/2014	9	33	Ap 5-10	156.440	16	7.701	4.695	64.026	1.64	95.375	0.675
161	16/07/2014	9	33	Ap 5-10	162.160	17	7.645	4.678	63.425	1.63	99.226	0.702
162	16/07/2014	9	33	Ap 5-10	169.180	18	7.228	4.422	63.455	1.63	103.502	0.732
163	16/07/2014	9	33	Bw 10-20	158.710	19	6.420	3.952	62.449	1.62	97.698	0.691
164	16/07/2014	9	33	Bw 10-20	153.740	20	7.483	4.813	55.475	1.55	98.884	0.699
165	16/07/2014	9	33	Bw 10-20	154.720	21	5.877	3.770	55.889	1.56	99.250	0.702
166	16/07/2014	9	33	Cu1 20-30	150.110	22	7.384	4.674	57.980	1.58	95.018	0.672
167	16/07/2014	9	33	Cu1 20-30	156.490	23	6.712	4.281	56.786	1.57	99.811	0.706
168	16/07/2014	9	33	Cu1 20-30	156.600	24	9.265	5.626	64.682	1.65	95.092	0.673

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
169	15/07/2014	9	32A	Ap 0-5	155.680	25	9.145	5.442	68.045	1.68	92.642	0.655
170	15/07/2014	9	32A	Ap 0-5	158.370	26	7.348	4.416	66.395	1.66	95.177	0.673
171	15/07/2014	9	32A	Ap 0-5	169.340	27	6.657	3.986	67.010	1.67	101.395	0.717
172	15/07/2014	9	32A	Ap 5-10	169.080	28	7.823	4.817	62.404	1.62	104.111	0.736
173	15/07/2014	9	32A	Ap 5-10	176.050	29	8.952	5.353	67.233	1.67	105.272	0.745
174	15/07/2014	9	32A	Ap 5-10	173.860	30	7.816	4.790	63.173	1.63	106.549	0.754
175	15/07/2014	9	32A	Ap 10-20	153.410	31	7.432	4.734	56.992	1.57	97.718	0.691
176	15/07/2014	9	32A	Ap 10-20	163.660	32	7.951	5.008	58.766	1.59	103.083	0.729
177	15/07/2014	9	32A	Ap 10-20	162.000	33	8.503	5.456	55.847	1.56	103.948	0.735
178	15/07/2014	9	32A	Bw 20-25	172.610	34	10.656	7.286	46.253	1.46	118.021	0.835
179	15/07/2014	9	32A	Bw 20-25	176.380	35	8.338	5.768	44.556	1.45	122.015	0.863
180	15/07/2014	9	32A	Bw 20-25	172.260	36	6.986	4.813	45.149	1.45	118.678	0.839

Spring

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
1	8/10/2014	15	8	Ap 0-5	155.261	1	9.180	5.557	65.197	1.65	93.985	0.665
2	8/10/2014	15	8	Ap 0-5	157.311	2	8.666	5.261	64.722	1.65	95.501	0.676
3	8/10/2014	15	8	Ap 0-5	158.035	3	8.446	5.183	62.956	1.63	96.980	0.686
4	8/10/2014	15	8	Ap 5-10	142.285	4	10.237	7.448	37.446	1.37	103.520	0.732
5	8/10/2014	15	8	Ap 5-10	159.447	5	8.761	6.128	42.967	1.43	111.527	0.789
6	8/10/2014	15	8	Ap 5-10	153.663	6	12.001	8.600	39.547	1.40	110.116	0.779
7	8/10/2014	15	8	Bw 10-20	125.380	7	8.948	6.224	43.766	1.44	87.211	0.617
8	8/10/2014	15	8	Bw 10-20	137.477	8	9.461	6.701	41.188	1.41	97.372	0.689
9	8/10/2014	15	8	Bw 10-20	140.432	9	8.504	6.102	39.364	1.39	100.766	0.713
10	8/10/2014	15	8	Cu 20-30	141.886	10	9.958	7.396	34.640	1.35	105.381	0.745
11	8/10/2014	15	8	Cu 20-30	149.223	11	12.318	9.488	29.827	1.30	114.940	0.813
12	8/10/2014	15	8	Cu 20-30	151.838	12	9.312	7.114	30.897	1.31	115.998	0.821
13	8/10/2014	15	15	Ap 0-5	145.835	13	9.678	5.873	64.788	1.65	88.499	0.626
14	8/10/2014	15	15	Ap 0-5	147.781	14	8.674	5.131	69.051	1.69	87.418	0.618
15	8/10/2014	15	15	Ap 0-5	143.958	15	10.177	6.326	60.876	1.61	89.484	0.633
16	8/10/2014	15	15	Ap 5-10	161.973	16	9.150	5.761	58.827	1.59	101.981	0.721

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
17	8/10/2014	15	15	Ap 5-10	157.368	17	8.933	5.571	60.348	1.60	98.141	0.694
18	8/10/2014	15	15	Ap 5-10	162.643	18	9.834	6.042	62.761	1.63	99.928	0.707
19	8/10/2014	15	15	Bw 10-20	170.600	19	11.645	7.844	48.457	1.48	114.915	0.813
20	8/10/2014	15	15	Bw 10-20	150.797	20	10.663	7.445	43.224	1.43	105.288	0.745
21	8/10/2014	15	15	Bw 10-20	154.490	21	11.271	7.531	49.661	1.50	103.226	0.730
22	8/10/2014	15	15	Cu1 20-30	151.488	22	12.641	9.240	36.807	1.37	110.731	0.783
23	8/10/2014	15	15	Cu1 20-30	166.634	23	12.496	9.318	34.106	1.34	124.255	0.879
24	8/10/2014	15	15	Cu1 20-30	165.945	24	10.849	7.496	44.731	1.45	114.658	0.811
25	8/10/2014	11	B12	Ap 0-5	158.629	49	10.103	6.433	57.050	1.57	101.006	0.714
26	8/10/2014	11	B12	Ap 0-5	164.950	50	10.384	6.310	64.564	1.65	100.234	0.709
27	8/10/2014	11	B12	Ap 0-5	164.357	51	10.813	6.460	67.384	1.67	98.192	0.695
28	8/10/2014	11	B12	Ap 5-10	166.896	52	10.289	7.025	46.463	1.46	113.951	0.806
29	8/10/2014	11	B12	Ap 5-10	156.894	53	11.256	7.668	46.792	1.47	106.882	0.756
30	8/10/2014	11	B12	Ap 5-10	158.577	54	10.816	7.341	47.337	1.47	107.629	0.761
31	8/10/2014	11	B12	AB 10-20	147.685	55	10.900	7.418	46.940	1.47	100.507	0.711
32	8/10/2014	11	B12	AB 10-20	146.375	56	10.340	7.062	46.417	1.46	99.971	0.707
33	8/10/2014	11	B12	AB 10-20	155.395	57	10.697	7.207	48.425	1.48	104.696	0.741
34	8/10/2014	11	B12	Bw 20-30	158.802	58	12.174	8.189	48.663	1.49	106.820	0.756
35	8/10/2014	11	B12	Bw 20-30	159.186	59	12.037	8.107	48.477	1.48	107.213	0.758
36	8/10/2014	11	B12	Bw 20-30	157.676	60	10.838	7.302	48.425	1.48	106.233	0.751
37	8/10/2014	15	37	Ap 0-5	167.420	25	12.501	7.753	61.241	1.61	103.832	0.734
38	8/10/2014	15	37	Ap 0-5	176.167	26	11.106	6.766	64.144	1.64	107.325	0.759
39	8/10/2014	15	37	Ap 0-5	170.760	27	13.155	8.233	59.784	1.60	106.869	0.756
40	8/10/2014	15	37	Ap 5-10	174.692	28	11.593	7.149	62.163	1.62	107.726	0.762
41	8/10/2014	15	37	Ap 5-10	175.862	29	11.679	7.157	63.183	1.63	107.770	0.762
42	8/10/2014	15	37	Ap 5-10	170.140	30	10.903	6.752	61.478	1.61	105.364	0.745
43	8/10/2014	15	37	Bw 10-20	147.208	31	9.889	5.788	70.853	1.71	86.160	0.609
44	8/10/2014	15	37	Bw 10-20	140.829	32	11.101	6.277	76.852	1.77	79.631	0.563
45	8/10/2014	15	37	Bw 10-20	153.542	33	10.762	6.139	75.305	1.75	87.585	0.620
46	8/10/2014	15	37	Cu 20-30	140.412	34	9.986	6.501	53.607	1.54	91.410	0.647
47	8/10/2014	15	37	Cu 20-30	151.435	35	12.671	8.183	54.845	1.55	97.798	0.692
48	8/10/2014	15	37	Cu 20-30	149.815	36	10.615	6.737	57.563	1.58	95.083	0.673
49	8/10/2014	15	35	Ap 0-5	150.211	37	9.515	5.954	59.809	1.60	93.994	0.665
50	8/10/2014	15	35	Ap 0-5	162.093	38	9.369	6.104	53.490	1.53	105.605	0.747

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
51	8/10/2014	15	35	Ap 0-5	166.508	39	10.707	6.557	63.291	1.63	101.970	0.721
52	8/10/2014	15	35	Ap 5-10	155.549	40	10.947	7.270	50.578	1.51	103.301	0.731
53	8/10/2014	15	35	Ap 5-10	173.858	41	13.124	8.555	53.407	1.53	113.331	0.802
54	8/10/2014	15	35	Ap 5-10	164.023	42	13.414	8.654	55.003	1.55	105.819	0.749
55	8/10/2014	15	35	Bw 10-20	152.232	43	10.145	7.232	40.279	1.40	108.521	0.768
56	8/10/2014	15	35	Bw 10-20	152.059	44	9.739	6.896	41.227	1.41	107.670	0.762
57	8/10/2014	15	35	Bw 10-20	153.609	45	11.440	7.925	44.353	1.44	106.412	0.753
58	8/10/2014	15	35	Cu 20-30	164.824	46	10.967	8.541	28.404	1.28	128.363	0.908
59	8/10/2014	15	35	Cu 20-30	151.512	47	12.493	9.888	26.345	1.26	119.919	0.848
60	8/10/2014	15	35	Cu 20-30	162.387	48	12.116	9.565	26.670	1.27	128.197	0.907
61	9/10/2014	14	147	Ap 0-5	172.228	25	12.794	9.108	40.470	1.40	122.608	0.867
62	9/10/2014	14	147	Ap 0-5	190.763	26	9.099	6.504	39.899	1.40	136.358	0.965
63	9/10/2014	14	147	Ap 0-5	189.631	27	10.091	7.453	35.395	1.35	140.057	0.991
64	9/10/2014	14	147	Ap 5-10	172.348	28	9.926	7.450	33.235	1.33	129.356	0.915
65	9/10/2014	14	147	Ap 5-10	159.333	29	10.268	7.911	29.794	1.30	122.758	0.868
66	9/10/2014	14	147	Ap 5-10	179.996	30	11.428	9.019	26.710	1.27	142.053	1.005
67	9/10/2014	14	147	Bw1 10-20	172.610	31	10.233	8.122	25.991	1.26	137.002	0.969
68	9/10/2014	14	147	Bw1 10-20	151.216	32	11.830	9.154	29.233	1.29	117.010	0.828
69	9/10/2014	14	147	Bw1 10-20	169.463	33	10.655	7.105	49.965	1.50	113.002	0.799
70	9/10/2014	14	147	Bw2 22-30	175.235	34	17.525	14.203	23.389	1.23	142.018	1.005
71	9/10/2014	14	147	Bw2 22-30	179.782	35	13.872	11.733	18.231	1.18	152.060	1.076
72	9/10/2014	14	147	Bw2 22-30	184.420	36	15.067	12.756	18.117	1.18	156.133	1.104
73	9/10/2014	14	149	Ap 0-5	166.507	37	8.726	5.194	68.002	1.68	99.110	0.701
74	9/10/2014	14	149	Ap 0-5	163.178	38	10.997	6.480	69.707	1.70	96.153	0.680
75	9/10/2014	14	149	Ap 0-5	151.688	39	8.877	5.474	62.167	1.62	93.538	0.662
76	9/10/2014	14	149	Ap 5-10	135.214	40	9.635	5.775	66.840	1.67	81.044	0.573
77	9/10/2014	14	149	Ap 5-10	136.330	41	9.470	5.897	60.590	1.61	84.893	0.600
78	9/10/2014	14	149	Ap 5-10	131.278	42	9.963	6.442	54.657	1.55	84.883	0.600
79	9/10/2014	14	149	Bw 10-22	154.399	43	9.152	6.534	40.067	1.40	110.232	0.780
80	9/10/2014	14	149	Bw 10-22	157.411	44	11.069	7.513	47.331	1.47	106.842	0.756
81	9/10/2014	14	149	Bw 10-22	146.434	45	11.406	8.123	40.416	1.40	104.286	0.738
82	9/10/2014	14	149	Cu 22- 30	132.623	46	10.381	7.134	45.514	1.46	91.141	0.645
83	9/10/2014	14	149	Cu 22- 30	143.613	47	10.914	8.392	30.052	1.30	110.427	0.781
84	9/10/2014	14	149	Cu 22- 30	150.575	48	11.244	8.340	34.820	1.35	111.686	0.790

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
85	9/10/2014	14	146	Ap1 0-5	204.942	49	13.264	6.993	89.675	1.90	108.049	0.764
86	9/10/2014	14	146	Ap1 0-5	188.539	50	11.898	7.810	52.343	1.52	123.759	0.875
87	9/10/2014	14	146	Ap1 0-5	191.154	51	9.602	6.201	54.846	1.55	123.448	0.873
88	9/10/2014	14	146	Ap1 5-10	164.474	52	11.189	7.878	42.028	1.42	115.804	0.819
89	9/10/2014	14	146	Ap1 5-10	182.548	53	10.903	9.340	16.734	1.17	156.379	1.106
90	9/10/2014	14	146	Ap1 5-10	185.499	54	9.375	6.540	43.349	1.43	129.404	0.915
91	9/10/2014	14	146	Ap2 10-20	155.206	55	10.666	8.064	32.267	1.32	117.343	0.830
92	9/10/2014	14	146	Ap2 10-20	161.505	56	9.647	7.308	32.006	1.32	122.347	0.865
93	9/10/2014	14	146	Ap2 10-20	153.891	57	10.989	7.305	50.431	1.50	102.300	0.724
94	9/10/2014	14	146	Bw 20-30	138.905	58	11.694	8.810	32.736	1.33	104.648	0.740
95	9/10/2014	14	146	Bw 20-30	156.733	59	11.012	8.350	31.880	1.32	118.845	0.841
96	9/10/2014	14	146	Bw 20-30	135.774	60	11.044	8.003	37.998	1.38	98.388	0.696
97	9/10/2014	14	148	Ap 0-5	161.284	61	9.234	5.672	62.800	1.63	99.069	0.701
98	9/10/2014	14	148	Ap 0-5	163.936	62	10.774	6.803	58.371	1.58	103.514	0.732
99	9/10/2014	14	148	Ap 0-5	160.698	63	9.970	5.929	68.157	1.68	95.565	0.676
100	9/10/2014	14	148	Ap 5-10	154.577	64	9.491	6.077	56.179	1.56	98.974	0.700
101	9/10/2014	14	148	Ap 5-10	149.086	65	9.746	6.134	58.885	1.59	93.833	0.664
102	9/10/2014	14	148	Ap 5-10	149.958	66	9.031	5.787	56.057	1.56	96.092	0.680
103	9/10/2014	14	148	Bw1 10-20	140.349	67	9.426	6.329	48.933	1.49	94.236	0.667
104	9/10/2014	14	148	Bw1 10-20	144.363	68	10.505	6.978	50.545	1.51	95.894	0.678
105	9/10/2014	14	148	Bw1 10-20	132.957	69	9.775	6.765	44.494	1.44	92.016	0.651
106	9/10/2014	14	148	Bw2 20-35	147.949	70	12.366	8.431	46.673	1.47	100.870	0.714
107	9/10/2014	14	148	Bw2 20-35	147.183	71	9.717	6.070	60.082	1.60	91.942	0.650
108	9/10/2014	14	148	Bw2 20-35	150.524	72	9.923	6.671	48.748	1.49	101.194	0.716
109	9/10/2014	14	125	Ap 0-5	158.510	73	10.894	7.028	55.009	1.55	102.259	0.723
110	9/10/2014	14	125	Ap 0-5	175.414	74	9.633	6.056	59.065	1.59	110.278	0.780
111	9/10/2014	14	125	Ap 0-5	173.463	75	9.847	6.265	57.175	1.57	110.363	0.781
112	9/10/2014	14	125	Ap 5-10	160.226	76	9.315	6.130	51.958	1.52	105.441	0.746
113	9/10/2014	14	125	Ap 5-10	176.611	77	9.763	6.616	47.567	1.48	119.682	0.847
114	9/10/2014	14	125	Ap 5-10	147.045	78	9.959	6.770	47.105	1.47	99.959	0.707
115	9/10/2014	14	125	Bw1 15-25	162.793	79	11.766	8.650	36.023	1.36	119.680	0.847
116	9/10/2014	14	125	Bw1 15-25	153.758	80	10.027	7.316	37.056	1.37	112.186	0.794
117	9/10/2014	14	125	Bw1 15-25	155.543	81	11.029	8.060	36.836	1.37	113.671	0.804
118	9/10/2014	14	125	Bw2 25-30	158.799	82	11.818	8.638	36.814	1.37	116.069	0.821

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
119	9/10/2014	14	125	Bw2 25-30	153.149	83	13.099	9.553	37.119	1.37	111.690	0.790
120	9/10/2014	14	125	Bw2 25-30	150.416	84	11.487	8.560	34.194	1.34	112.089	0.793
121	8/10/2014	11	A16	Ap 0-5	173.140	61	12.750	7.986	59.654	1.60	108.447	0.767
122	8/10/2014	11	A16	Ap 0-5	169.255	62	11.719	7.143	64.063	1.64	103.165	0.730
123	8/10/2014	11	A16	Ap 0-5	164.803	63	9.771	6.104	60.075	1.60	102.953	0.728
124	8/10/2014	11	A16	Ap 5-10	166.573	64	12.938	8.975	44.156	1.44	115.551	0.817
125	8/10/2014	11	A16	Ap 5-10	166.378	65	11.719	8.210	42.741	1.43	116.560	0.824
126	8/10/2014	11	A16	Ap 5-10	150.643	66	11.687	8.221	42.160	1.42	105.967	0.750
127	8/10/2014	11	A16	AB 10-20	159.286	67	10.408	7.206	44.435	1.44	110.282	0.780
128	8/10/2014	11	A16	AB 10-20	165.312	68	11.566	8.158	41.775	1.42	116.602	0.825
129	8/10/2014	11	A16	AB 10-20	158.796	69	10.529	7.368	42.902	1.43	111.123	0.786
130	8/10/2014	11	A16	Bw 20-30	126.726	70	14.138	10.933	29.315	1.29	97.998	0.693
131	8/10/2014	11	A16	Bw 20-30	164.422	71	15.064	12.219	23.283	1.23	133.369	0.943
132	8/10/2014	11	A16	Bw 20-30	155.916	72	14.962	12.522	19.486	1.19	130.489	0.923
133	9/10/2014	15	17	Ap 0-5	144.772	73	9.754	5.980	63.110	1.63	88.757	0.628
134	9/10/2014	15	17	Ap 0-5	148.059	74	10.160	6.312	60.963	1.61	91.983	0.651
135	9/10/2014	15	17	Ap 0-5	151.055	75	9.429	5.824	61.899	1.62	93.302	0.660
136	9/10/2014	15	17	Ap 5-10	163.755	76	9.958	6.498	53.247	1.53	106.857	0.756
137	9/10/2014	15	17	Ap 5-10	141.845	77	11.661	7.481	55.875	1.56	90.999	0.644
138	9/10/2014	15	17	Ap 5-10	155.919	78	9.537	6.091	56.575	1.57	99.581	0.704
139	9/10/2014	15	17	bAh 10-20	150.279	79	12.104	8.303	45.779	1.46	103.087	0.729
140	9/10/2014	15	17	bAh 10-20	139.473	80	11.253	7.738	45.425	1.45	95.907	0.678
141	9/10/2014	15	17	bAh 10-20	147.739	81	10.203	6.851	48.927	1.49	99.202	0.702
142	9/10/2014	15	17	Cu 20-30	153.283	82	11.801	7.708	53.101	1.53	100.119	0.708
143	9/10/2014	15	17	Cu 20-30	148.615	83	12.427	7.962	56.079	1.56	95.218	0.674
144	9/10/2014	15	17	Cu 20-30	153.988	84	13.588	8.604	57.927	1.58	97.506	0.690
145	9/10/2014	9	31B	Ap 0-5	147.984	85	8.828	5.257	67.928	1.68	88.123	0.623
146	9/10/2014	9	31B	Ap 0-5	155.696	86	9.303	5.498	69.207	1.69	92.015	0.651
147	9/10/2014	9	31B	Ap 0-5	160.177	87	8.425	4.970	69.517	1.70	94.490	0.668
148	9/10/2014	9	31B	Ap 5-10	136.870	88	10.210	6.694	52.525	1.53	89.736	0.635
149	9/10/2014	9	31B	Ap 5-10	128.411	89	10.647	6.869	55.001	1.55	82.845	0.586
150	9/10/2014	9	31B	Ap 5-10	133.246	90	8.812	5.859	50.401	1.50	88.594	0.627
151	9/10/2014	9	31B	Bw1 15-25	107.014	91	8.787	6.042	45.432	1.45	73.584	0.520
152	9/10/2014	9	31B	Bw1 15-25	116.247	92	9.476	6.536	44.982	1.45	80.180	0.567

Sample Number	Date Sampled	Farm	Paddock	Horizon – Depth (Cm)	BD Wet Weight (G)	Can number	Can Wet Weight (G)	Can Dry Weight (G)	Moisture Content (%)	Moisture Factor	Equivalent Oven Dry Mass (G)	Bulk Density (Mg Cm^{-3})
153	9/10/2014	9	31B	Bw1 15-25	121.463	93	8.925	6.170	44.652	1.45	83.969	0.594
154	9/10/2014	9	31B	Cu1 25-30	109.016	94	10.724	7.608	40.957	1.41	77.340	0.547
155	9/10/2014	9	31B	Cu1 25-30	103.472	95	8.019	5.721	40.168	1.40	73.820	0.522
156	9/10/2014	9	31B	Cu1 25-30	116.154	96	9.413	6.664	41.252	1.41	82.232	0.582
157	9/10/2014	9	33	Ap 0-5	147.976	97	10.920	6.124	78.315	1.78	82.986	0.587
158	9/10/2014	9	33	Ap 0-5	139.386	98	8.458	4.899	72.647	1.73	80.734	0.571
159	9/10/2014	9	33	Ap 0-5	155.877	99	9.886	5.801	70.419	1.70	91.467	0.647
160	9/10/2014	9	33	Ap 5-10	133.158	100	9.467	5.904	60.349	1.60	83.043	0.587
161	9/10/2014	9	33	Ap 5-10	125.145	101	9.253	5.863	57.820	1.58	79.296	0.561
162	9/10/2014	9	33	Ap 5-10	148.278	102	10.179	6.369	59.821	1.60	92.778	0.656
163	9/10/2014	9	33	Bw 10-20	118.116	103	8.686	6.675	30.127	1.30	90.770	0.642
164	9/10/2014	9	33	Bw 10-20	122.911	104	9.904	7.205	37.460	1.37	89.416	0.632
165	9/10/2014	9	33	Bw 10-20	125.837	105	9.035	6.749	33.872	1.34	93.998	0.665
166	9/10/2014	9	33	Cu1 20-30	123.718	106	10.745	8.007	34.195	1.34	92.193	0.652
167	9/10/2014	9	33	Cu1 20-30	118.460	107	10.482	8.399	24.801	1.25	94.919	0.671
168	9/10/2014	9	33	Cu1 20-30	132.033	108	10.633	7.948	33.782	1.34	98.693	0.698
169	9/10/2014	9	32A	Ap 0-5	178.030	109	12.044	7.141	68.660	1.69	105.556	0.747
170	9/10/2014	9	32A	Ap 0-5	171.186	110	11.260	6.729	67.335	1.67	102.301	0.724
171	9/10/2014	9	32A	Ap 0-5	162.146	111	9.963	5.950	67.445	1.67	96.835	0.685
172	9/10/2014	9	32A	Ap 5-10	155.237	112	11.005	6.731	63.497	1.63	94.948	0.672
173	9/10/2014	9	32A	Ap 5-10	160.666	113	13.470	8.383	60.682	1.61	99.990	0.707
174	9/10/2014	9	32A	Ap 5-10	167.064	114	15.584	9.635	61.744	1.62	103.289	0.731
175	9/10/2014	9	32A	Ap 10-20	145.690	115	10.580	6.776	56.139	1.56	93.308	0.660
176	9/10/2014	9	32A	Ap 10-20	154.646	116	11.292	7.168	57.533	1.58	98.167	0.694
177	9/10/2014	9	32A	Ap 10-20	164.506	117	11.211	7.011	59.906	1.60	102.877	0.728
178	9/10/2014	9	32A	Bw 20-25	132.500	118	9.838	6.329	55.443	1.55	85.240	0.603
179	9/10/2014	9	32A	Bw 20-25	130.097	119	10.844	7.036	54.122	1.54	84.412	0.597
180	9/10/2014	9	32A	Bw 20-25	138.567	120	12.225	7.970	53.388	1.53	90.338	0.639

Appendix 5 – Penetration Resistance Measurements

Summer

Date	Farm	Paddock	Horizon	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10	Average Reading
13/01/2014	15	8	Ap 0-5	1	3	0	5	2	1	6	7	2	10	**3.7**
13/01/2014	15	8	Ap 5-10	11	11	10	14	14	15	11	15	9	13	**12.3**
13/01/2014	15	8	Bw 10-20	16	25	14	13	14	10	13	11	20	18	**15.4**
13/01/2014	15	8	Bah 20-28	10	9	13	15	13	8	10	11	16	15	**12**
21/01/2014	15	15	Ap 0-5	6	1	14	1	6	3	1	4	10	4	**5**
21/01/2014	15	15	Ap 5-10	22	23	16	18	14	12	16	15	24	27	**18.7**
21/01/2014	15	15	Bw 10-15	14	26	20	28	15	15	23	15	26	28	**21**
21/01/2014	15	15	Cu1 15-25	20	24	17	15	10	15	18	17	16	24	**17.6**
22/01/2014	11	B12	Ap 0-5	2	2	1	4	4	2	7	2	6	6	**3.6**
22/01/2014	11	B12	Ap 5-10	18	17	18	14	10	6	5	6	5	4	**10.3**
22/01/2014	11	B12	Bw 10-20	9	13	17	18	9	17	18	18	18	19	**15.6**
22/01/2014	11	B12	Cu 20-30	13	15	9	13	20	9	20	22	30	16	**16.7**
22/01/2014	15	37	Ap 0-5	6	4	5	2	9	2	4	4	3	7	**4.6**
22/01/2014	15	37	Ap 5-10	4	21	20	15	16	16	12	15	11	11	**14.1**
22/01/2014	15	37	Bw 14-20	13	13	13	8	10	13	12	11	11	15	**11.9**
22/01/2014	15	37	Bw 20-30	13	13	13	8	10	13	12	11	11	15	**11.9**
22/01/2014	15	35	Ap 0-5	4	3	4	8	6	3	3	5	5	13	**5.4**
22/01/2014	15	35	Ap 5-10	16	14	18	15	25	16	25	14	12	13	**16.8**
22/01/2014	15	35	Bw 10-25	32	14	25	16	15	14	18	23	22	27	**20.6**
22/01/2014	15	35	Cu 25-30	28	8	13	13	25	22	25	23	12	19	**18.8**
23/01/2014	14	147	Ap 0-5	1	2	2	1	1	7	7	5	5	5	**3.6**
23/01/2014	14	147	Ap 5-10	13	9	12	6	12	14	10	13	15	8	**11.2**
23/01/2014	14	147	Ap 10-20	27	29	40	40	40	27	30	33	40	40	**34.6**
23/01/2014	14	147	Bw1 22-30	39	30	25	28	32	35	40	30	35	30	**32.4**
23/01/2014	14	149	Ap 0-5	7	5	6	5	4	8	4	5	7	8	**5.9**
23/01/2014	14	149	Ap 5-10	20	15	12	15	15	17	15	14	22	24	**16.9**
23/01/2014	14	149	Bw 10-22	40	28	34	20	38	21	37	34	29	28	**30.9**
23/01/2014	14	149	Cu 22- on	37	40	38	36	34	40	35	38	38	37	**37.3**

Date	Farm	Paddock	Horizon	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10	Average Reading
22/01/2014	14	146	Ap 0-5	0	1	1	5	3	2	7	1	1	4	**2.5**
22/01/2014	14	146	Ap 5-10	14	25	12	15	20	18	9	15	14	12	**15.4**
22/01/2014	14	146	Ap2 10-15	21	22	18	22	18	15	20	20	24	19	**19.9**
22/01/2014	14	146	Bw 15-28	19	19	17	16	20	16	23	14	17	18	**17.9**
23/01/2014	14	148	Ap 0-5	17	13	16	18	13	18	19	19	17	21	**17.1**
23/01/2014	14	148	Ap 5-10	18	17	15	13	10	17	22	18	20	23	**17.3**
23/01/2014	14	148	Bw1 10-20	23	22	27	32	29	29	33	32	30	22	**27.9**
23/01/2014	14	148	Bw2 20-35	39	40	40	40	40	39	27	39	33	34	**37.1**
23/01/2014	14	125	Ap 0-5	0	0	0	0	2	2	2	1	2	0	**0.9**
23/01/2014	14	125	Ap 5-10	11	15	13	21	24	25	30	17	10	20	**18.6**
23/01/2014	14	125	Ap 10-15	25	27	25	20	26	26	23	23	22	17	**23.4**
23/01/2014	14	125	Bw1 15-25	29	33	30	39	23	27	23	24	24	25	**27.7**
23/01/2014	14	125	Bw2 25-40	36	25	27	30	36	38	40	30	22	34	**31.8**
23/01/2014	11	A16	Ap 0-5	0	2	0	3	0	0	1	2	5	0	**1.3**
23/01/2014	11	A16	Ap 5-10	11	17	8	10	11	10	13	13	12	10	**11.5**
23/01/2014	11	A16	AB 10-20	28	21	27	18	24	25	25	20	26	27	**24.1**
23/01/2014	11	A16	Bw 20-30	14	16	23	33	40	15	17	19	21	20	**21.8**
22/01/2014	15	17	Ap 0-5	4	3	4	15	10	8	14	13	6	12	**8.9**
22/01/2014	15	17	Ap 5-10	8	11	13	10	13	17	10	18	18	20	**13.8**
22/01/2014	15	17	Bw 10-20	20	10	15	20	15	20	10	14	19	26	**16.9**
22/01/2014	15	17	bAh 18-23	11	15	10	14	21	13	9	11	14	10	**12.8**
22/01/2014	15	17	bBw 20-30	29	24	16	21	25	15	14	15	17	16	**19.2**
24/01/2014	9	31B	Ap 0-5	2	3	0	9	3	3	4	4	5	10	**4.3**
24/01/2014	9	31B	Ap 5-10	20	22	14	23	25	28	29	27	30	31	**24.9**
24/01/2014	9	31B	Bw 15-25	23	24	23	25	22	24	24	23	30	32	**25**
24/01/2014	9	31B	Cu1 25-40	28	26	27	25	21	20	25	23	25	23	**24.3**
24/01/2014	9	33	Ap 0-5	3	2	5	5	7	6	3	7	7	8	**5.3**
24/01/2014	9	33	Ap 5-10	16	16	12	17	15	22	18	10	10	10	**14.6**
24/01/2014	9	33	Ap 10-15	20	21	16	15	20	21	18	20	15	14	**18**
24/01/2014	9	33	Bw 15-25	24	23	23	27	22	22	24	23	21	18	**22.7**
24/01/2014	9	32A	Ap 0-5	0	0	0	0	0	8	2	4	4	6	**2.4**
24/01/2014	9	32A	Ap 5-10	20	15	21	18	26	16	20	13	15	20	**18.4**
24/01/2014	9	32A	Ap 10-20	20	14	16	15	20	20	17	16	16	18	**17.2**
24/01/2014	9	32A	Bw 20-25	24	22	26	27	24	21	15	19	17	18	**21.3**

Autumn

Date	Farm	Paddock	Horizon	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10	Average Reading
7/04/2014	15	8	Ap 0-5	1	5	7	6	2	1	5	18	17	15	**7.7**
7/04/2014	15	8	Ap 5-10	17	12	12	16	10	13	15	11	17	16	**13.9**
7/04/2014	15	8	Bw 10-20	21	30	33	27	22	27	30	29	28	26	**27.3**
7/04/2014	15	8	bAh 20-24	21	17	19	22	20	20	17	16	18	16	**18.6**
7/04/2014	15	15	Ap 0-5	1	2	2	8	3	2	7	7	3	0	**3.5**
7/04/2014	15	15	Ap 5-10	31	25	25	31	19	26	16	14	26	30	**24.3**
7/04/2014	15	15	Bw 11-18	31	35	33	30	30	32	16	25	27	31	**29**
7/04/2014	15	15	Cu1 18-30	24	31	20	26	27	23	27	18	27	20	**24.3**
7/04/2014	11	B12	Ap 0-5	1	2	6	2	7	6	6	7	7	16	**6**
7/04/2014	11	B12	Ap 5-10	20	12	25	24	26	17	19	28	26	20	**21.7**
7/04/2014	11	B12	Bw 15-20	17	12	16	26	17	21	25	20	17	19	**19**
7/04/2014	11	B12	Cu 20-30	10	9	27	32	35	32	20	20	17	37	**23.9**
7/04/2014	15	37	Ap 0-5	4	13	6	6	10	5	8	15	12	10	**8.9**
7/04/2014	15	37	Ap 5-10	30	25	30	30	24	23	19	19	19	22	**24.1**
7/04/2014	15	37	Bw 10-20	20	20	17	15	21	25	18	32	40	40	**24.8**
7/04/2014	15	37	Bw 20-30	28	40	31	37	40	40	25	30	25	34	**33**
7/04/2014	15	35	Ap 0-5	5	7	6	6	4	10	3	4	8	2	**5.5**
7/04/2014	15	35	Ap 5-10	12	18	18	13	19	15	20	16	18	15	**16.4**
7/04/2014	15	35	Bw 10-20	15	25	25	26	20	24	18	22	23	13	**21.1**
7/04/2014	15	35	Cu 20-30	22	17	18	15	12	15	14	18	13	17	**16.1**
8/04/2014	14	147	Ap 0-5	11	6	5	2	6	4	9	13	10	10	**7.6**
8/04/2014	14	147	Ap 5-10	13	14	17	18	23	20	27	15	21	22	**19**
8/04/2014	14	147	Ap 10-20	40	40	40	37	40	38	40	40	36	37	**38.8**
8/04/2014	14	147	Bw1 20-30	33	32	37	40	40	34	37	38	30	30	**35.1**
8/04/2014	14	149	Ap 0-5	5	4	7	5	5	8	7	15	1	14	**7.1**
8/04/2014	14	149	Ap 5-10	21	31	27	20	18	21	15	25	10	25	**21.3**
8/04/2014	14	149	Bw 10-20	21	29	27	23	35	23	20	23	35	23	**25.9**
8/04/2014	14	149	Cu 20-30	34	20	33	20	26	29	38	38	40	37	**31.5**
8/04/2014	14	146	Ap 0-5	13	18	13	15	20	20	14	19	14	15	**16.1**
8/04/2014	14	146	Ap 5-12	23	16	22	15	22	22	22	17	17	40	**21.6**
8/04/2014	14	146	Bw 12-20	40	34	40	40	40	40	40	40	40	31	**38.5**
8/04/2014	14	146	Bw 20-30	40	31	34	40	40	40	38	40	38	39	**38**
8/04/2014	14	148	Ap 0-5	7	16	30	6	13	9	17	31	31	10	**17**

Date	Farm	Paddock	Horizon	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10	Average Reading
8/04/2014	14	148	Ap 5-10	36	34	35	40	28	28	30	21	37	38	**32.7**
8/04/2014	14	148	Bw1 10-20	30	34	35	40	28	28	30	21	37	38	**32.1**
8/04/2014	14	148	Bw2 20-30	29	32	40	24	26	25	23	26	30	21	**27.6**
8/04/2014	14	125	Ap 0-5	9	3	6	8	10	8	12	16	14	6	**9.2**
8/04/2014	14	125	Ap 5-10	35	31	28	30	18	23	23	27	22	22	**25.9**
8/04/2014	14	125	Bw1 10-20	31	31	33	33	28	33	38	26	26	30	**30.9**
8/04/2014	14	125	Bw2 20-30	25	34	35	37	40	30	40	40	32	32	**34.5**
7/04/2014	11	A16	Ap 0-5	11	15	25	17	18	10	16	10	10	13	**14.5**
7/04/2014	11	A16	Ap 5-10	20	22	22	35	22	21	17	23	22	26	**23**
7/04/2014	11	A16	AB 10-20	15	24	22	31	25	34	28	23	26	25	**25.3**
7/04/2014	11	A16	Cu 20-30	19	20	35	32	23	25	26	24	19	23	**24.6**
8/04/2014	15	17	Ap 0-5	15	9	9	7	15	16	4	7	17	12	**11.1**
8/04/2014	15	17	Ap 5-10	21	18	25	25	26	26	19	23	24	25	**23.2**
8/04/2014	15	17	Bw 10-14	24	17	23	18	19	19	24	25	21	24	**21.4**
8/04/2014	15	17	bAh 14-18	15	20	19	20	19	23	23	20	20	19	**19.8**
8/04/2014	15	17	bBw 18-30	31	28	31	38	33	38	37	34	36	31	**33.7**
8/04/2014	9	31B	Ap 0-5	5	10	9	5	17	14	17	14	18	13	**12.2**
8/04/2014	9	31B	Ap 5-10	21	17	26	20	13	18	26	24	20	18	**20.3**
8/04/2014	9	31B	Bw 12-25	20	35	40	40	33	34	25	25	33	30	**31.5**
8/04/2014	9	31B	Cu1 25-30	27	30	31	29	30	21	21	33	22	21	**26.5**
8/04/2014	9	33	Ap 0-5	4	12	6	3	0	2	4	11	10	14	**6.6**
8/04/2014	9	33	Ap 5-10	20	10	16	16	25	35	24	21	25	25	**21.7**
8/04/2014	9	33	Ap 10-18	27	36	25	22	23	27	23	24	24	26	**25.7**
8/04/2014	9	33	Bw 18-26	20	26	28	18	18	22	22	16	23	20	**21.3**
8/04/2014	9	32A	Ap 0-5	23	17	22	13	11	11	21	21	13	12	**16.4**
8/04/2014	9	32A	Ap 5-10	36	40	40	40	36	35	32	40	36	28	**36.3**
8/04/2014	9	32A	Bw 10-18	36	37	33	30	35	31	28	30	27	23	**31**
8/04/2014	9	32A	Cu 18- 30	25	20	21	28	25	26	26	25	18	22	**23.6**

Winter

Date	Farm	Paddock	Horizon	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10	Average Reading
14/07/2014	15	8	Ap 0-5	7	6	11	9	10	9	9	9	8	10	**8.8**
14/07/2014	15	8	Ap 5-10	19	13	6	11	36	22	20	11	14	11	**16.3**
14/07/2014	15	8	Bw 10-20	19	13	17	15	15	14	17	20	19	12	**16.1**
14/07/2014	15	8	Cu 20-30	33	15	26	19	21	24	19	14	20	20	**21.1**
14/07/2014	15	15	Ap 0-5	3	3	3	0	2	5	4	7	5	5	**3.7**
14/07/2014	15	15	Ap 5-10	12	15	15	15	10	11	13	14	11	15	**13.1**
14/07/2014	15	15	Bw 11-18	15	25	28	20	18	20	27	19	33	24	**22.9**
14/07/2014	15	15	Cu1 18-30	28	28	28	17	29	34	33	23	20	20	**26**
14/07/2014	11	B12	Ap 0-5	0	8	9	5	6	8	7	12	13	13	**8.1**
14/07/2014	11	B12	Ap 5-10	15	12	14	17	18	20	17	17	19	16	**16.5**
14/07/2014	11	B12	AB 10-20	16	20	19	20	17	16	16	15	15	11	**16.5**
14/07/2014	11	B12	Bw 20-30	10	10	10	14	10	11	11	12	12	8	**10.8**
15/07/2014	15	37	Ap 0-5	1	6	0	4	0	5	4	4	2	8	**3.4**
15/07/2014	15	37	Ap 5-10	7	0	5	23	10	12	12	7	10	11	**9.7**
15/07/2014	15	37	Bw 10-20	14	11	13	12	16	14	14	16	13	20	**14.3**
15/07/2014	15	37	Bw 20-30	10	10	10	8	9	8	8	9	10	10	**9.2**
14/07/2014	15	35	Ap 0-5	0	4	5	7	10	4	2	9	13	15	**6.9**
14/07/2014	15	35	Ap 5-10	18	19	22	20	18	12	16	16	13	22	**17.6**
14/07/2014	15	35	Bw 10-20	17	11	16	18	12	12	12	16	19	12	**14.5**
14/07/2014	15	35	Cu 20-30	12	14	15	18	16	16	15	14	14	14	**14.8**
15/07/2014	14	147	Ap 0-5	0	5	3	14	7	11	1	1	11	5	**5.8**
15/07/2014	14	147	Ap 5-10	19	11	19	13	16	18	17	11	17	17	**15.8**
15/07/2014	14	147	Bw1 10-20	19	24	22	17	22	18	18	14	15	12	**18.1**
15/07/2014	14	147	Bw2 20-30	9	14	17	10	9	17	5	7	9	8	**10.5**
15/07/2014	14	149	Ap 0-5	0	0	1	0	0	0	0	0	0	0	**0.1**
15/07/2014	14	149	Ap 5-10	0	3	1	3	2	0	2	1	3	3	**1.8**
15/07/2014	14	149	Bw 10-20	15	18	14	8	6	7	11	12	12	12	**11.5**
15/07/2014	14	149	Cu 20-30	10	13	13	13	12	17	11	15	10	10	**12.4**
15/07/2014	14	146	Ap1 0-5	1	5	2	1	10	5	2	2	9	6	**4.3**
15/07/2014	14	146	Ap1 5-12	11	8	13	10	12	13	15	13	11	15	**12.1**
15/07/2014	14	146	Ap2 12-20	15	17	13	12	13	17	13	16	14	13	**14.3**
15/07/2014	14	146	Bw 20-30	25	17	17	30	28	11	14	10	17	20	**18.9**
15/07/2014	14	148	Ap 0-5	6	5	11	10	5	9	11	7	12	15	**9.1**

Date	Farm	Paddock	Horizon	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10	Average Reading
15/07/2014	14	148	Ap 5-10	14	15	12	12	14	19	18	19	17	20	**16**
15/07/2014	14	148	Bw1 10-20	19	15	16	12	13	20	17	13	18	15	**15.8**
15/07/2014	14	148	Bw2 20-30	21	17	14	14	13	13	19	19	19	18	**16.7**
15/07/2014	14	125	Ap 0-5	3	3	2	3	2	3	6	6	2	2	**3.2**
15/07/2014	14	125	Ap 5-10	10	8	8	9	12	14	18	15	10	16	**12**
15/07/2014	14	125	Bw1 10-20	18	16	17	19	12	12	10	13	14	18	**14.9**
15/07/2014	14	125	Bw2 20-30	19	26	20	18	20	25	24	23	18	21	**21.4**
14/07/2014	11	A16	Ap 0-5	5	3	0	6	6	0	5	8	2	3	**3.8**
14/07/2014	11	A16	Ap 5-10	16	12	11	10	9	13	11	10	10	12	**11.4**
14/07/2014	11	A16	AB 10-20	26	28	23	19	19	22	23	19	19	24	**22.2**
14/07/2014	11	A16	Bw 20-30	17	18	19	18	17	14	17	18	12	16	**16.6**
14/07/2014	15	17	Ap 0-5	2	3	1	0	0	4	7	2	2	6	**2.7**
14/07/2014	15	17	Ap 5-10	2	10	11	9	10	9	10	10	16	13	**10**
14/07/2014	15	17	bAh 10-20	16	14	13	13	8	15	12	13	17	14	**13.5**
14/07/2014	15	17	bBw 20-30	10	10	9	7	7	9	12	9	9	7	**8.9**
15/07/2014	9	31B	Ap 0-5	2	7	4	1	5	6	9	9	10	7	**6**
15/07/2014	9	31B	Ap 5-10	13	10	9	5	5	12	10	10	12	10	**9.6**
15/07/2014	9	31B	Bw 10-20	18	12	19	22	18	17	20	20	20	20	**18.6**
15/07/2014	9	31B	Cu1 20-30	16	17	18	15	9	18	14	15	18	12	**15.2**
16/07/2014	9	33	Ap 0-5	4	8	7	7	9	6	8	6	8	11	**7.4**
16/07/2014	9	33	Ap 5-10	9	5	10	10	9	7	9	8	13	10	**9**
16/07/2014	9	33	Bw 10-20	11	12	11	12	10	13	12	21	13	10	**12.5**
16/07/2014	9	33	Cu 20-30	7	12	9	10	6	8	10	8	9	10	**8.9**
15/07/2014	9	32A	Ap 0-5	1	0	0	0	0	0	9	9	13	9	**4.1**
15/07/2014	9	32A	Ap 5-10	2	2	8	7	8	15	10	12	10	6	**8**
15/07/2014	9	32A	Ap 10-20	10	12	12	11	12	13	12	12	11	3	**10.8**
15/07/2014	9	32A	Bw 20-30	11	13	16	7	10	11	10	8	10	11	**10.7**

Spring

Date	Farm	Paddock	Horizon	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10	Average Reading
8/10/2014	15	8	Ap 0-5	5	6	4	5	9	5	6	4	8	7	**5.9**
8/10/2014	15	8	Ap 5-10	7	8	10	9	12	9	5	9	8	6	**8.3**
8/10/2014	15	8	Bw 10-20	16	21	19	13	17	16	15	14	10	10	**15.1**
8/10/2014	15	8	Cu 20-30	10	7	8	8	10	11	9	8	7	10	**8.8**
8/10/2014	15	15	Ap 0-5	1	1	0	2	2	1	1	3	3	6	**2**
8/10/2014	15	15	Ap 5-10	8	7	10	13	10	12	13	13	10	14	**11**
8/10/2014	15	15	Bw 11-18	17	20	14	13	16	19	11	17	18	14	**15.9**
8/10/2014	15	15	Cu1 18-30	11	14	12	13	11	12	18	16	12	16	**13.5**
8/10/2014	11	B12	Ap 0-5	3	4	3	3	8	5	6	7	5	3	**4.7**
8/10/2014	11	B12	Ap 5-10	14	14	15	17	20	14	14	13	18	18	**15.7**
8/10/2014	11	B12	AB 10-20	15	15	19	12	15	16	13	16	16	16	**15.3**
8/10/2014	11	B12	Bw 20-30	16	20	16	18	20	22	16	13	18	21	**18**
8/10/2014	15	37	Ap 0-5	4	10	10	5	6	5	13	13	6	4	**7.6**
8/10/2014	15	37	Ap 5-10	11	12	14	17	16	18	17	18	16	17	**15.6**
8/10/2014	15	37	Bw 10-20	13	15	13	14	15	15	14	16	16	17	**14.8**
8/10/2014	15	37	Bw 20-30	10	10	12	12	11	13	10	12	11	11	**11.2**
8/10/2014	15	35	Ap 0-5	3	3	3	3	3	1	1	2	1	4	**2.4**
8/10/2014	15	35	Ap 5-10	10	13	17	14	18	12	17	13	14	16	**14.4**
8/10/2014	15	35	Bw 10-20	19	13	13	15	14	18	16	16	17	14	**15.5**
8/10/2014	15	35	Cu 20-30	14	13	13	14	13	14	16	17	15	14	**14.3**
9/10/2014	14	147	Ap 0-5	4	7	3	7	5	5	9	8	12	6	**6.6**
9/10/2014	14	147	Ap 5-10	12	11	8	7	13	10	12	11	12	12	**10.8**
9/10/2014	14	147	Bw1 10-20	8	9	22	20	13	20	16	17	16	14	**15.5**
9/10/2014	14	147	Bw2 20-30	16	14	15	10	14	13	15	13	13	11	**13.4**
9/10/2014	14	149	Ap 0-5	2	2	3	5	1	5	1	4	3	4	**3**
9/10/2014	14	149	Ap 5-10	5	5	4	3	4	7	3	6	2	3	**4.2**
9/10/2014	14	149	Bw 10-20	9	5	6	4	5	6	8	11	13	11	**7.8**
9/10/2014	14	149	Cu 20-30	17	13	13	13	18	12	13	11	12	15	**13.7**
9/10/2014	14	146	Ap1 0-5	8	11	10	10	9	6	8	9	5	9	**8.5**
9/10/2014	14	146	Ap1 5-12	7	10	15	14	14	12	15	18	20	14	**13.9**
9/10/2014	14	146	Ap2 12-20	29	15	18	17	17	17	19	18	17	21	**18.8**
9/10/2014	14	146	Bw 20-30	18	40	32	30	22	33	23	15	12	22	**24.7**
9/10/2014	14	148	Ap 0-5	3	10	10	12	5	19	12	10	5	9	**9.5**

Date	Farm	Paddock	Horizon	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10	Average Reading
9/10/2014	14	148	Ap 5-10	12	20	15	21	18	17	18	18	15	18	**17.2**
9/10/2014	14	148	Bw1 10-20	17	15	17	19	18	17	20	19	20	16	**17.8**
9/10/2014	14	148	Bw2 20-30	16	12	15	12	12	10	12	12	10	11	**12.2**
9/10/2014	14	125	Ap 0-5	5	6	6	9	7	2	6	12	6	5	**6.4**
9/10/2014	14	125	Ap 5-10	10	14	11	15	13	10	13	17	14	12	**12.9**
9/10/2014	14	125	Bw1 10-20	27	22	22	22	19	21	22	23	18	17	**21.3**
9/10/2014	14	125	Bw2 20-30	15	20	19	23	20	19	22	18	21	17	**19.4**
8/10/2014	11	A16	Ap 0-5	3	6	7	6	5	2	4	5	7	5	**5**
8/10/2014	11	A16	Ap 5-10	7	12	13	14	12	11	14	15	10	15	**12.3**
8/10/2014	11	A16	AB 10-20	15	15	16	14	12	15	13	15	11	10	**13.6**
8/10/2014	11	A16	Bw 20-30	12	11	15	10	12	10	12	11	11	11	**11.5**
8/10/2014	15	17	Ap 0-5	4	4	3	2	5	5	5	4	5	7	**4.4**
8/10/2014	15	17	Ap 5-10	8	6	4	7	8	10	11	6	2	17	**7.9**
8/10/2014	15	17	bAh 10-20	14	12	11	12	10	10	10	11	13	12	**11.5**
8/10/2014	15	17	bBw 20-30	13	13	12	10	8	7	12	13	9	14	**11.1**
9/10/2014	9	31B	Ap 0-5	6	8	8	4	3	3	6	4	6	6	**5.4**
9/10/2014	9	31B	Ap 5-10	14	13	12	14	12	16	14	17	11	13	**13.6**
9/10/2014	9	31B	Bw 10-20	15	20	20	20	20	17	19	21	17	23	**19.2**
9/10/2014	9	31B	Cu1 20-30	22	20	15	18	16	20	14	17	20	16	**17.8**
9/10/2014	9	33	Ap 0-5	4	7	4	4	6	6	2	4	1	4	**4.2**
9/10/2014	9	33	Ap 5-10	7	9	12	11	14	11	14	11	12	10	**11.1**
9/10/2014	9	33	Bw 10-20	13	15	15	17	15	15	16	18	16	17	**15.7**
9/10/2014	9	33	Cu 20-30	13	14	16	17	12	14	13	13	12	12	**13.6**
9/10/2014	9	32A	Ap 0-5	2	7	8	6	4	7	2	5	1	13	**5.5**
9/10/2014	9	32A	Ap 5-10	11	3	14	13	14	10	11	11	8	11	**10.6**
9/10/2014	9	32A	Ap 10-20	8	7	11	9	13	13	16	14	18	17	**12.6**
9/10/2014	9	32A	Bw 20-30	20	14	18	15	15	16	15	18	17	16	**16.4**

Appendix 6 – Dry Root Density Measurements

Summer

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
1	13/01/2014	15	8	Ap 0-5	0.2556	0.0018	1.8080
2	13/01/2014	15	8	Ap 0-5	0.2788	0.0020	1.9721
3	13/01/2014	15	8	Ap 0-5	0.0989	0.0007	0.6996
4	13/01/2014	15	8	Ap 5-10	0.1233	0.0009	0.8722
5	13/01/2014	15	8	Ap 5-10	0.1031	0.0007	0.7293
6	13/01/2014	15	8	Ap 5-10	0.1470	0.0010	1.0398
7	13/01/2014	15	8	Bw 10-20	0.0362	0.0003	0.2561
8	13/01/2014	15	8	Bw 10-20	0.0103	0.0001	0.0729
9	13/01/2014	15	8	Bw 10-20	0.0238	0.0002	0.1684
10	13/01/2014	15	8	Bah 20-30	0.0149	0.0001	0.1054
11	13/01/2014	15	8	Bah 20-30	0.0148	0.0001	0.1047
12	13/01/2014	15	8	Bah 20-30	0.0291	0.0002	0.2058
13	21/01/2014	15	15	Ap 0-5	0.2671	0.0019	1.8893
14	21/01/2014	15	15	Ap 0-5	0.3999	0.0028	2.8287
15	21/01/2014	15	15	Ap 0-5	0.3467	0.0025	2.4524
16	21/01/2014	15	15	Ap 5-10	0.1650	0.0012	1.1671
17	21/01/2014	15	15	Ap 5-10	0.1645	0.0012	1.1636
18	21/01/2014	15	15	Ap 5-10	0.1568	0.0011	1.1091
19	21/01/2014	15	15	Bw 10-20	0.0628	0.0004	0.4442
20	21/01/2014	15	15	Bw 10-20	0.0762	0.0005	0.5390
21	21/01/2014	15	15	Bw 10-20	0.1375	0.0010	0.9726
22	21/01/2014	15	15	Cu 20-30	0.0510	0.0004	0.3608
23	21/01/2014	15	15	Cu 20-30	0.1259	0.0009	0.8906
24	21/01/2014	15	15	Cu 20-30	0.0441	0.0003	0.3119
25	22/01/2014	11	B12	Ap 0-5	0.1916	0.0014	1.3553
26	22/01/2014	11	B12	Ap 0-5	0.1509	0.0011	1.0674
27	22/01/2014	11	B12	Ap 0-5	0.5003	0.0035	3.5389
28	22/01/2014	11	B12	Ap 5-10	0.1787	0.0013	1.2640
29	22/01/2014	11	B12	Ap 5-10	0.1211	0.0009	0.8566
30	22/01/2014	11	B12	Ap 5-10	0.1376	0.0010	0.9733
31	22/01/2014	11	B12	Bw 10-20	0.0855	0.0006	0.6048
32	22/01/2014	11	B12	Bw 10-20	0.0780	0.0006	0.5517
33	22/01/2014	11	B12	Bw 10-20	0.0530	0.0004	0.3749
34	22/01/2014	11	B12	no samples			
35	22/01/2014	11	B12	no samples			
36	22/01/2014	11	B12	no samples			
37	22/01/2014	15	37	Ap 0-5	0.4108	0.0029	2.9058
38	22/01/2014	15	37	Ap 0-5	0.3030	0.0021	2.1433
39	22/01/2014	15	37	Ap 0-5	0.3371	0.0024	2.3845
40	22/01/2014	15	37	Ap 5-10	0.0439	0.0003	0.3105
41	22/01/2014	15	37	Ap 5-10	0.0187	0.0001	0.1323
42	22/01/2014	15	37	Ap 5-10	0.0287	0.0002	0.2030
43	22/01/2014	15	37	Bw 10-20	0.0145	0.0001	0.1026
44	22/01/2014	15	37	Bw 10-20	0.0330	0.0002	0.2334
45	22/01/2014	15	37	Bw 10-20	0.0230	0.0002	0.1627
46	22/01/2014	15	37	Bw 20-30	0.0171	0.0001	0.1210
47	22/01/2014	15	37	Bw 20-30	0.0173	0.0001	0.1224

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
48	22/01/2014	15	37	Bw 20-30	0.0256	0.0002	0.1811
49	22/01/2014	15	35	Ap 0-5	0.5227	0.0037	3.6973
50	22/01/2014	15	35	Ap 0-5	0.5314	0.0038	3.7589
51	22/01/2014	15	35	Ap 0-5	0.2379	0.0017	1.6828
52	22/01/2014	15	35	Ap 5-10	0.0342	0.0002	0.2419
53	22/01/2014	15	35	Ap 5-10	0.0112	0.0001	0.0792
54	22/01/2014	15	35	Ap 5-10	0.0318	0.0002	0.2249
55	22/01/2014	15	35	Bw 10-20	0.0695	0.0005	0.4916
56	22/01/2014	15	35	Bw 10-20	0.0178	0.0001	0.1259
57	22/01/2014	15	35	Bw 10-20	0.0921	0.0007	0.6515
58	22/01/2014	15	35	Cu 20-30	n/r	0.0000	0.0000
59	22/01/2014	15	35	Cu 20-30	0.0090	0.0001	0.0637
60	22/01/2014	15	35	Cu 20-30	0.0104	0.0001	0.0736
61	23/01/2014	14	147	Ap 0-5	0.9384	0.0066	6.6378
62	23/01/2014	14	147	Ap 0-5	0.3189	0.0023	2.2558
63	23/01/2014	14	147	Ap 0-5	0.2674	0.0019	1.8915
64	23/01/2014	14	147	Ap 5-10	0.1030	0.0007	0.7286
65	23/01/2014	14	147	Ap 5-10	0.1641	0.0012	1.1608
66	23/01/2014	14	147	Ap 5-10	0.1198	0.0008	0.8474
67	23/01/2014	14	147	Ap 10-20	0.1984	0.0014	1.4034
68	23/01/2014	14	147	Ap 10-20	0.0830	0.0006	0.5871
69	23/01/2014	14	147	Ap 10-20	0.1222	0.0009	0.8644
70	23/01/2014	14	147	Bw 22-30	0.0120	0.0001	0.0849
71	23/01/2014	14	147	Bw 22-30	0.0085	0.0001	0.0601
72	23/01/2014	14	147	Bw 22-30	0.0132	0.0001	0.0934
73	23/01/2014	14	149	Ap 0-5	0.1484	0.0010	1.0497
74	23/01/2014	14	149	Ap 0-5	0.2573	0.0018	1.8200
75	23/01/2014	14	149	Ap 0-5	0.1340	0.0009	0.9479
76	23/01/2014	14	149	Ap 5-10	0.0883	0.0006	0.6246
77	23/01/2014	14	149	Ap 5-10	0.0819	0.0006	0.5793
78	23/01/2014	14	149	Ap 5-10	0.0734	0.0005	0.5192
79	23/01/2014	14	149	Bw 10-22	0.0372	0.0003	0.2631
80	23/01/2014	14	149	Bw 10-22	0.0178	0.0001	0.1259
81	23/01/2014	14	149	Bw 10-22	0.0161	0.0001	0.1139
82	23/01/2014	14	149	Cu 22- 30	n/r	0.0000	0.0000
83	23/01/2014	14	149	Cu 22- 30	n/r	0.0000	0.0000
84	23/01/2014	14	149	Cu 22- 30	0.0072	0.0001	0.0509
85	22/01/2014	14	146	Ap 0-5	0.3753	0.0027	2.6547
86	22/01/2014	14	146	Ap 0-5	0.2922	0.0021	2.0669
87	22/01/2014	14	146	Ap 0-5	0.3534	0.0025	2.4998
88	22/01/2014	14	146	Ap 5-10	0.0760	0.0005	0.5376
89	22/01/2014	14	146	Ap 5-10	0.0649	0.0005	0.4591
90	22/01/2014	14	146	Ap 5-10	0.0781	0.0006	0.5524
91	22/01/2014	14	146	Ap2 10-15	0.0370	0.0003	0.2617
92	22/01/2014	14	146	Ap2 10-15	0.0526	0.0004	0.3721
93	22/01/2014	14	146	Ap2 10-15	0.0570	0.0004	0.4032
94	22/01/2014	14	146	Bw 15-28	0.0229	0.0002	0.1620
95	22/01/2014	14	146	Bw 15-28	0.0244	0.0002	0.1726
96	22/01/2014	14	146	Bw 15-28	0.0547	0.0004	0.3869
97	23/01/2014	14	148	Ap 0-5	0.5826	0.0041	4.1211
98	23/01/2014	14	148	Ap 0-5	0.2488	0.0018	1.7599
99	23/01/2014	14	148	Ap 0-5	1.2327	0.0087	8.7196
100	23/01/2014	14	148	Ap 5-10	0.2150	0.0015	1.5208
101	23/01/2014	14	148	Ap 5-10	0.0793	0.0006	0.5609
102	23/01/2014	14	148	Ap 5-10	0.1198	0.0008	0.8474
103	23/01/2014	14	148	Bw1 10-20	0.0585	0.0004	0.4138
104	23/01/2014	14	148	Bw1 10-20	0.0384	0.0003	0.2716

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
105	23/01/2014	14	148	Bw1 10-20	0.0569	0.0004	0.4025
106	23/01/2014	14	148	Bw2 20-30	0.0012	0.0000	0.0085
107	23/01/2014	14	148	Bw2 20-30	n/r	0.0000	0.0000
108	23/01/2014	14	148	Bw2 20-30	0.0027	0.0000	0.0191
109	23/01/2014	14	125	Ap 0-5	0.2058	0.0015	1.4557
110	23/01/2014	14	125	Ap 0-5	0.9895	0.0070	6.9993
111	23/01/2014	14	125	Ap 0-5	0.1292	0.0009	0.9139
112	23/01/2014	14	125	Ap 5-10	0.0774	0.0005	0.5475
113	23/01/2014	14	125	Ap 5-10	0.0585	0.0004	0.4138
114	23/01/2014	14	125	Ap 5-10	0.1243	0.0009	0.8792
115	23/01/2014	14	125	Bw1 15-25	0.0190	0.0001	0.1344
116	23/01/2014	14	125	Bw1 15-25	0.0220	0.0002	0.1556
117	23/01/2014	14	125	Bw1 15-25	0.0216	0.0002	0.1528
118	23/01/2014	14	125	Bw2 25-30	n/r	0.0000	0.0000
119	23/01/2014	14	125	Bw2 25-30	0.0129	0.0001	0.0912
120	23/01/2014	14	125	Bw2 25-30	0.0060	0.0000	0.0424
121	23/01/2014	11	A16	Ap 0-5	0.2639	0.0019	1.8667
122	23/01/2014	11	A16	Ap 0-5	0.1865	0.0013	1.3192
123	23/01/2014	11	A16	Ap 0-5	0.3036	0.0021	2.1475
124	23/01/2014	11	A16	Ap 5-10	0.1768	0.0013	1.2506
125	23/01/2014	11	A16	Ap 5-10	0.1308	0.0009	0.9252
126	23/01/2014	11	A16	Ap 5-10	0.2284	0.0016	1.6156
127	23/01/2014	11	A16	AB 10-20	0.0398	0.0003	0.2815
128	23/01/2014	11	A16	AB 10-20	0.0549	0.0004	0.3883
129	23/01/2014	11	A16	AB 10-20	0.0269	0.0002	0.1903
130	23/01/2014	11	A16	Bw 20-30	0.0306	0.0002	0.2165
131	23/01/2014	11	A16	Bw 20-30	0.0147	0.0001	0.1040
132	23/01/2014	11	A16	Bw 20-30	0.0154	0.0001	0.1089
133	22/01/2014	15	17	Ap 0-5	0.2268	0.0016	1.6043
134	22/01/2014	15	17	Ap 0-5	0.1591	0.0011	1.1254
135	22/01/2014	15	17	Ap 0-5	0.1100	0.0008	0.7781
136	22/01/2014	15	17	Ap 5-10	0.0105	0.0001	0.0743
137	22/01/2014	15	17	Ap 5-10	0.0258	0.0002	0.1825
138	22/01/2014	15	17	Ap 5-10	0.0153	0.0001	0.1082
139	22/01/2014	15	17	Bw 10-20	0.0094	0.0001	0.0665
140	22/01/2014	15	17	Bw 10-20	0.0243	0.0002	0.1719
141	22/01/2014	15	17	Bw 10-20	0.0066	0.0000	0.0467
142	22/01/2014	15	17	bBw 20-30	0.0119	0.0001	0.0842
143	22/01/2014	15	17	bBw 20-30	0.0037	0.0000	0.0262
144	22/01/2014	15	17	bBw 20-30	0.0220	0.0002	0.1556
145	24/01/2014	9	31B	Ap 0-5	0.4471	0.0032	3.1626
146	24/01/2014	9	31B	Ap 0-5	0.4646	0.0033	3.2864
147	24/01/2014	9	31B	Ap 0-5	0.4766	0.0034	3.3713
148	24/01/2014	9	31B	Ap 5-10	0.1284	0.0009	0.9082
149	24/01/2014	9	31B	Ap 5-10	0.0955	0.0007	0.6755
150	24/01/2014	9	31B	Ap 5-10	0.0882	0.0006	0.6239
151	24/01/2014	9	31B	Bw 15-25	0.0237	0.0002	0.1676
152	24/01/2014	9	31B	Bw 15-25	0.0478	0.0003	0.3381
153	24/01/2014	9	31B	Bw 15-25	0.0387	0.0003	0.2737
154	24/01/2014	9	31B	Cu1 25-30	0.0142	0.0001	0.1004
155	24/01/2014	9	31B	Cu1 25-30	0.0040	0.0000	0.0283
156	24/01/2014	9	31B	Cu1 25-30	0.0044	0.0000	0.0311
157	24/01/2014	9	33	Ap 0-5	0.1559	0.0011	1.1028
158	24/01/2014	9	33	Ap 0-5	0.2212	0.0016	1.5647
159	24/01/2014	9	33	Ap 0-5	0.0981	0.0007	0.6939
160	24/01/2014	9	33	Ap 5-10	0.0245	0.0002	0.1733
161	24/01/2014	9	33	Ap 5-10	0.0445	0.0003	0.3148

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
162	24/01/2014	9	33	Ap 5-10	0.0181	0.0001	0.1280
163	24/01/2014	9	33	Bw 15-25	0.0303	0.0002	0.2143
164	24/01/2014	9	33	Bw 15-25	0.0230	0.0002	0.1627
165	24/01/2014	9	33	Bw 15-25	0.0079	0.0001	0.0559
166	24/01/2014	9	33	Cu1 25-30	0.0185	0.0001	0.1309
167	24/01/2014	9	33	Cu1 25-30	0.0029	0.0000	0.0205
168	24/01/2014	9	33	Cu1 25-30	0.0091	0.0001	0.0644
169	24/01/2014	9	32A	Ap 0-5	0.1039	0.0007	0.7349
170	24/01/2014	9	32A	Ap 0-5	0.1757	0.0012	1.2428
171	24/01/2014	9	32A	Ap 0-5	0.2080	0.0015	1.4713
172	24/01/2014	9	32A	Ap 5-10	0.1042	0.0007	0.7371
173	24/01/2014	9	32A	Ap 5-10	0.0248	0.0002	0.1754
174	24/01/2014	9	32A	Ap 5-10	0.0486	0.0003	0.3438
175	24/01/2014	9	32A	Ap 10-20	0.0710	0.0005	0.5022
176	24/01/2014	9	32A	Ap 10-20	0.0276	0.0002	0.1952
177	24/01/2014	9	32A	Ap 10-20	0.0581	0.0004	0.4110
178	24/01/2014	9	32A	Bw 20-25	0.0273	0.0002	0.1931
179	24/01/2014	9	32A	Bw 20-25	0.0163	0.0001	0.1153
180	24/01/2014	9	32A	Bw 20-25	0.0288	0.0002	0.2037

Autumn

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
1	7/04/2014	15	8	Ap 0-5	0.2262	0.0016	1.6000
2	7/04/2014	15	8	Ap 0-5	0.1497	0.0011	1.0589
3	7/04/2014	15	8	Ap 0-5	0.3777	0.0027	2.6717
4	7/04/2014	15	8	Ap 5-10	0.1680	0.0012	1.1884
5	7/04/2014	15	8	Ap 5-10	0.0774	0.0005	0.5475
6	7/04/2014	15	8	Ap 5-10	0.1469	0.0010	1.0391
7	7/04/2014	15	8	Bw 10-20	0.0184	0.0001	0.1302
8	7/04/2014	15	8	Bw 10-20	0.0220	0.0002	0.1556
9	7/04/2014	15	8	Bw 10-20	0.0100	0.0001	0.0707
10	7/04/2014	15	8	Bah 20-30	0.0133	0.0001	0.0941
11	7/04/2014	15	8	Bah 20-30	0.0129	0.0001	0.0912
12	7/04/2014	15	8	Bah 20-30	0.0162	0.0001	0.1146
13	7/04/2014	15	15	Ap 0-5	0.2895	0.0020	2.0478
14	7/04/2014	15	15	Ap 0-5	0.2222	0.0016	1.5717
15	7/04/2014	15	15	Ap 0-5	0.2190	0.0015	1.5491
16	7/04/2014	15	15	Ap 5-10	0.0802	0.0006	0.5673
17	7/04/2014	15	15	Ap 5-10	0.1545	0.0011	1.0929
18	7/04/2014	15	15	Ap 5-10	0.1237	0.0009	0.8750
19	7/04/2014	15	15	Bw 10-20	0.0051	0.0000	0.0361
20	7/04/2014	15	15	Bw 10-20	0.0051	0.0000	0.0361
21	7/04/2014	15	15	Bw 10-20	0.0035	0.0000	0.0248
22	7/04/2014	15	15	Cu1 20-30	0.0101	0.0001	0.0714
23	7/04/2014	15	15	Cu1 20-30	0.0071	0.0001	0.0502
24	7/04/2014	15	15	Cu1 20-30	0.0082	0.0001	0.0580
25	7/04/2014	11	B12	Ap 0-5	0.2430	0.0017	1.7189
26	7/04/2014	11	B12	Ap 0-5	0.2372	0.0017	1.6778
27	7/04/2014	11	B12	Ap 0-5	0.0755	0.0005	0.5341
28	7/04/2014	11	B12	Ap 5-10	0.0412	0.0003	0.2914
29	7/04/2014	11	B12	Ap 5-10	0.0580	0.0004	0.4103
30	7/04/2014	11	B12	Ap 5-10	0.0398	0.0003	0.2815
31	7/04/2014	11	B12	Bw 10-20	0.0210	0.0001	0.1485
32	7/04/2014	11	B12	Bw 10-20	0.0514	0.0004	0.3636
33	7/04/2014	11	B12	Bw 10-20	0.0298	0.0002	0.2108

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
34	7/04/2014	11	B12	Cu1 20-30	n/r	0.0000	0.0000
35	7/04/2014	11	B12	Cu1 20-30	0.0071	0.0001	0.0502
36	7/04/2014	11	B12	Cu1 20-30	0.0034	0.0000	0.0241
37	7/04/2014	15	37	Ap 0-5	0.1758	0.0012	1.2435
38	7/04/2014	15	37	Ap 0-5	0.2057	0.0015	1.4550
39	7/04/2014	15	37	Ap 0-5	0.2316	0.0016	1.6382
40	7/04/2014	15	37	Ap 5-10	0.0602	0.0004	0.4258
41	7/04/2014	15	37	Ap 5-10	0.0330	0.0002	0.2334
42	7/04/2014	15	37	Ap 5-10	0.0489	0.0003	0.3459
43	7/04/2014	15	37	Bw 10-20	0.0359	0.0003	0.2539
44	7/04/2014	15	37	Bw 10-20	0.0234	0.0002	0.1655
45	7/04/2014	15	37	Bw 10-20	0.0169	0.0001	0.1195
46	7/04/2014	15	37	Bw 20-30	0.0038	0.0000	0.0269
47	7/04/2014	15	37	Bw 20-30	0.0328	0.0002	0.2320
48	7/04/2014	15	37	Bw 20-30	0.0059	0.0000	0.0417
49	7/04/2014	15	35	Ap 0-5	0.6864	0.0049	4.8553
50	7/04/2014	15	35	Ap 0-5	0.4829	0.0034	3.4158
51	7/04/2014	15	35	Ap 0-5	0.3153	0.0022	2.2303
52	7/04/2014	15	35	Ap 5-10	0.0238	0.0002	0.1684
53	7/04/2014	15	35	Ap 5-10	0.0434	0.0003	0.3070
54	7/04/2014	15	35	Ap 5-10	0.0390	0.0003	0.2759
55	7/04/2014	15	35	Bw 10-20	0.0183	0.0001	0.1294
56	7/04/2014	15	35	Bw 10-20	0.0164	0.0001	0.1160
57	7/04/2014	15	35	Bw 10-20	0.0176	0.0001	0.1245
58	7/04/2014	15	35	Cu 20-30	0.0169	0.0001	0.1195
59	7/04/2014	15	35	Cu 20-30	0.0322	0.0002	0.2278
60	7/04/2014	15	35	Cu 20-30	0.0162	0.0001	0.1146
61	8/04/2014	14	147	Ap 0-5	0.2377	0.0017	1.6814
62	8/04/2014	14	147	Ap 0-5	0.4888	0.0035	3.4576
63	8/04/2014	14	147	Ap 0-5	0.3940	0.0028	2.7870
64	8/04/2014	14	147	Ap 5-10	0.1248	0.0009	0.8828
65	8/04/2014	14	147	Ap 5-10	0.0982	0.0007	0.6946
66	8/04/2014	14	147	Ap 5-10	0.1707	0.0012	1.2075
67	8/04/2014	14	147	Ap 10-20	0.0618	0.0004	0.4371
68	8/04/2014	14	147	Ap 10-20	0.0350	0.0002	0.2476
69	8/04/2014	14	147	Ap 10-20	0.0077	0.0001	0.0545
70	8/04/2014	14	147	Bw 22-30	0.0040	0.0000	0.0283
71	8/04/2014	14	147	Bw 22-30	0.0004	0.0000	0.0028
72	8/04/2014	14	147	Bw 22-30	0.0004	0.0000	0.0028
73	8/04/2014	14	149	Ap 0-5	0.3870	0.0027	2.7375
74	8/04/2014	14	149	Ap 0-5	0.2263	0.0016	1.6007
75	8/04/2014	14	149	Ap 0-5	0.4065	0.0029	2.8754
76	8/04/2014	14	149	Ap 5-10	0.0710	0.0005	0.5022
77	8/04/2014	14	149	Ap 5-10	0.0686	0.0005	0.4852
78	8/04/2014	14	149	Ap 5-10	0.0605	0.0004	0.4280
79	8/04/2014	14	149	Bw 10-22	0.0392	0.0003	0.2773
80	8/04/2014	14	149	Bw 10-22	0.0416	0.0003	0.2943
81	8/04/2014	14	149	Bw 10-22	0.0526	0.0004	0.3721
82	8/04/2014	14	149	Cu 22- 30	0.0103	0.0001	0.0729
83	8/04/2014	14	149	Cu 22- 30	0.0157	0.0001	0.1111
84	8/04/2014	14	149	Cu 22- 30	0.0237	0.0002	0.1676
85	8/04/2014	14	146	Ap 0-5	0.2677	0.0019	1.8936
86	8/04/2014	14	146	Ap 0-5	0.1770	0.0013	1.2520
87	8/04/2014	14	146	Ap 0-5	0.2046	0.0014	1.4473
88	8/04/2014	14	146	Ap 5-10	0.1613	0.0011	1.1410
89	8/04/2014	14	146	Ap 5-10	0.2759	0.0020	1.9516
90	8/04/2014	14	146	Ap 5-10	0.1628	0.0012	1.1516

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
91	8/04/2014	14	146	Ap2 10-15	0.1356	0.0010	0.9592
92	8/04/2014	14	146	Ap2 10-15	0.1306	0.0009	0.9238
93	8/04/2014	14	146	Ap2 10-15	0.1350	0.0010	0.9549
94	8/04/2014	14	146	Bw 15-28	0.0021	0.0000	0.0149
95	8/04/2014	14	146	Bw 15-28	0.0028	0.0000	0.0198
96	8/04/2014	14	146	Bw 15-28	0.0238	0.0002	0.1684
97	8/04/2014	14	148	Ap 0-5	0.3810	0.0027	2.6950
98	8/04/2014	14	148	Ap 0-5	0.4636	0.0033	3.2793
99	8/04/2014	14	148	Ap 0-5	0.4808	0.0034	3.4010
100	8/04/2014	14	148	Ap 5-10	0.1854	0.0013	1.3114
101	8/04/2014	14	148	Ap 5-10	0.0982	0.0007	0.6946
102	8/04/2014	14	148	Ap 5-10	0.1144	0.0008	0.8092
103	8/04/2014	14	148	Bw1 10-20	0.0935	0.0007	0.6614
104	8/04/2014	14	148	Bw1 10-20	0.0590	0.0004	0.4173
105	8/04/2014	14	148	Bw1 10-20	0.0764	0.0005	0.5404
106	8/04/2014	14	148	Bw2 20-30	0.0465	0.0003	0.3289
107	8/04/2014	14	148	Bw2 20-30	0.0569	0.0004	0.4025
108	8/04/2014	14	148	Bw2 20-30	0.0546	0.0004	0.3862
109	8/04/2014	14	125	Ap 0-5	0.6687	0.0047	4.7301
110	8/04/2014	14	125	Ap 0-5	0.6940	0.0049	4.9090
111	8/04/2014	14	125	Ap 0-5	0.4956	0.0035	3.5057
112	8/04/2014	14	125	Ap 5-10	0.1465	0.0010	1.0363
113	8/04/2014	14	125	Ap 5-10	0.1128	0.0008	0.7979
114	8/04/2014	14	125	Ap 5-10	0.2041	0.0014	1.4437
115	8/04/2014	14	125	Bw1 15-25	0.1140	0.0008	0.8064
116	8/04/2014	14	125	Bw1 15-25	0.0755	0.0005	0.5341
117	8/04/2014	14	125	Bw1 15-25	0.0978	0.0007	0.6918
118	8/04/2014	14	125	Bw2 25-30	0.0144	0.0001	0.1019
119	8/04/2014	14	125	Bw2 25-30	0.0320	0.0002	0.2264
120	8/04/2014	14	125	Bw2 25-30	0.0395	0.0003	0.2794
121	7/04/2014	11	A16	Ap 0-5	0.0185	0.0001	0.1309
122	7/04/2014	11	A16	Ap 0-5	0.1990	0.0014	1.4076
123	7/04/2014	11	A16	Ap 0-5	0.0447	0.0003	0.3162
124	7/04/2014	11	A16	Ap 5-10	0.0895	0.0006	0.6331
125	7/04/2014	11	A16	Ap 5-10	0.0242	0.0002	0.1712
126	7/04/2014	11	A16	Ap 5-10	0.0147	0.0001	0.1040
127	7/04/2014	11	A16	AB 10-20	0.0285	0.0002	0.2016
128	7/04/2014	11	A16	AB 10-20	0.0024	0.0000	0.0170
129	7/04/2014	11	A16	AB 10-20	0.0165	0.0001	0.1167
130	7/04/2014	11	A16	Bw 20-30	n/r	0.0000	0.0000
131	7/04/2014	11	A16	Bw 20-30	0.0014	0.0000	0.0099
132	7/04/2014	11	A16	Bw 20-30	0.0166	0.0001	0.1174
133	8/04/2014	15	17	Ap 0-5	0.6400	0.0045	4.5271
134	8/04/2014	15	17	Ap 0-5	0.0475	0.0003	0.3360
135	8/04/2014	15	17	Ap 0-5	0.0549	0.0004	0.3883
136	8/04/2014	15	17	Ap 5-10	0.0800	0.0006	0.5659
137	8/04/2014	15	17	Ap 5-10	0.0520	0.0004	0.3678
138	8/04/2014	15	17	Ap 5-10	0.0292	0.0002	0.2065
139	8/04/2014	15	17	Bw 10-20	0.0112	0.0001	0.0792
140	8/04/2014	15	17	Bw 10-20	0.0163	0.0001	0.1153
141	8/04/2014	15	17	Bw 10-20	0.0105	0.0001	0.0743
142	8/04/2014	15	17	bBw 20-30	0.0142	0.0001	0.1004
143	8/04/2014	15	17	bBw 20-30	0.0090	0.0001	0.0637
144	8/04/2014	15	17	bBw 20-30	0.0107	0.0001	0.0757
145	8/04/2014	9	31B	Ap 0-5	0.4536	0.0032	3.2086
146	8/04/2014	9	31B	Ap 0-5	0.4628	0.0033	3.2736
147	8/04/2014	9	31B	Ap 0-5	0.3731	0.0026	2.6391

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
148	8/04/2014	9	31B	Ap 5-10	0.1320	0.0009	0.9337
149	8/04/2014	9	31B	Ap 5-10	0.1774	0.0013	1.2548
150	8/04/2014	9	31B	Ap 5-10	0.1640	0.0012	1.1601
151	8/04/2014	9	31B	Bw 15-25	0.0436	0.0003	0.3084
152	8/04/2014	9	31B	Bw 15-25	0.0536	0.0004	0.3791
153	8/04/2014	9	31B	Bw 15-25	0.0670	0.0005	0.4739
154	8/04/2014	9	31B	Cu1 25-30	0.0456	0.0003	0.3226
155	8/04/2014	9	31B	Cu1 25-30	0.0299	0.0002	0.2115
156	8/04/2014	9	31B	Cu1 25-30	0.0384	0.0003	0.2716
157	8/04/2014	9	33	Ap 0-5	0.1343	0.0009	0.9500
158	8/04/2014	9	33	Ap 0-5	0.1395	0.0010	0.9868
159	8/04/2014	9	33	Ap 0-5	0.1751	0.0012	1.2386
160	8/04/2014	9	33	Ap 5-10	0.0831	0.0006	0.5878
161	8/04/2014	9	33	Ap 5-10	0.1178	0.0008	0.8333
162	8/04/2014	9	33	Ap 5-10	0.0908	0.0006	0.6423
163	8/04/2014	9	33	Bw 15-25	0.0215	0.0002	0.1521
164	8/04/2014	9	33	Bw 15-25	0.0554	0.0004	0.3919
165	8/04/2014	9	33	Bw 15-25	0.0252	0.0002	0.1783
166	8/04/2014	9	33	Cu1 25-30	0.0126	0.0001	0.0891
167	8/04/2014	9	33	Cu1 25-30	0.0293	0.0002	0.2073
168	8/04/2014	9	33	Cu1 25-30	0.0000	0.0000	0.0000
169	8/04/2014	9	32A	Ap 0-5	0.1631	0.0012	1.1537
170	8/04/2014	9	32A	Ap 0-5	0.3514	0.0025	2.4856
171	8/04/2014	9	32A	Ap 0-5	0.1324	0.0009	0.9365
172	8/04/2014	9	32A	Ap 5-10	0.0291	0.0002	0.2058
173	8/04/2014	9	32A	Ap 5-10	0.0928	0.0007	0.6564
174	8/04/2014	9	32A	Ap 5-10	0.0697	0.0005	0.4930
175	8/04/2014	9	32A	Ap 10-20	0.0427	0.0003	0.3020
176	8/04/2014	9	32A	Ap 10-20	0.1240	0.0009	0.8771
177	8/04/2014	9	32A	Ap 10-20	0.0636	0.0004	0.4499
178	8/04/2014	9	32A	Bw 20-25	0.0069	0.0000	0.0488
179	8/04/2014	9	32A	Bw 20-25	0.0138	0.0001	0.0976
180	8/04/2014	9	32A	Bw 20-25	0.0136	0.0001	0.0962

Winter

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
1	14/07/2014	15	8	Ap 0-5	0.5845	0.0041	4.1345
2	14/07/2014	15	8	Ap 0-5	0.2590	0.0018	1.8321
3	14/07/2014	15	8	Ap 0-5	0.6539	0.0046	4.6254
4	14/07/2014	15	8	Ap 5-10	0.1380	0.0010	0.9762
5	14/07/2014	15	8	Ap 5-10	0.1762	0.0012	1.2464
6	14/07/2014	15	8	Ap 5-10	0.1941	0.0014	1.3730
7	14/07/2014	15	8	Bw 10-20	0.0206	0.0001	0.1457
8	14/07/2014	15	8	Bw 10-20	0.0137	0.0001	0.0969
9	14/07/2014	15	8	Bw 10-20	0.0907	0.0006	0.6416
10	14/07/2014	15	8	Bah 20-30	0.0001	0.0000	0.0007
11	14/07/2014	15	8	Bah 20-30	0.0070	0.0000	0.0495
12	14/07/2014	15	8	Bah 20-30	0.0094	0.0001	0.0665
13	14/07/2014	15	15	Ap 0-5	0.2754	0.0019	1.9481
14	14/07/2014	15	15	Ap 0-5	0.1574	0.0011	1.1134
15	14/07/2014	15	15	Ap 0-5	0.6704	0.0047	4.7421
16	14/07/2014	15	15	Ap 5-10	0.0965	0.0007	0.6826
17	14/07/2014	15	15	Ap 5-10	0.1003	0.0007	0.7095
18	14/07/2014	15	15	Ap 5-10	0.0837	0.0006	0.5921
19	14/07/2014	15	15	Bw 10-20	0.0515	0.0004	0.3643

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
20	14/07/2014	15	15	Bw 10-20	0.0706	0.0005	0.4994
21	14/07/2014	15	15	Bw 10-20	0.0556	0.0004	0.3933
22	14/07/2014	15	15	Cu1 20-30	0.0186	0.0001	0.1316
23	14/07/2014	15	15	Cu1 20-30	0.0631	0.0004	0.4463
24	14/07/2014	15	15	Cu1 20-30	0.0012	0.0000	0.0085
25	14/07/2014	11	B12	Ap 0-5	0.0925	0.0007	0.6543
26	14/07/2014	11	B12	Ap 0-5	0.9815	0.0069	6.9427
27	14/07/2014	11	B12	Ap 0-5	0.1450	0.0010	1.0257
28	14/07/2014	11	B12	Ap 5-10	0.0525	0.0004	0.3714
29	14/07/2014	11	B12	Ap 5-10	0.0412	0.0003	0.2914
30	14/07/2014	11	B12	Ap 5-10	0.0689	0.0005	0.4874
31	14/07/2014	11	B12	Bw 10-20	0.0134	0.0001	0.0948
32	14/07/2014	11	B12	Bw 10-20	0.0040	0.0000	0.0283
33	14/07/2014	11	B12	Bw 10-20	0.0109	0.0001	0.0771
34	14/07/2014	11	B12	Cu1 20-30	0.0023	0.0000	0.0163
35	14/07/2014	11	B12	Cu1 20-30	0.0041	0.0000	0.0290
36	14/07/2014	11	B12	Cu1 20-30	0.0081	0.0001	0.0573
37	15/07/2014	15	37	Ap 0-5	0.6234	0.0044	4.4097
38	15/07/2014	15	37	Ap 0-5	0.9145	0.0065	6.4688
39	15/07/2014	15	37	Ap 0-5	0.5522	0.0039	3.9060
40	15/07/2014	15	37	Ap 5-10	0.1991	0.0014	1.4083
41	15/07/2014	15	37	Ap 5-10	0.4435	0.0031	3.1371
42	15/07/2014	15	37	Ap 5-10	0.2233	0.0016	1.5795
43	15/07/2014	15	37	Bw 10-20	0.0206	0.0001	0.1457
44	15/07/2014	15	37	Bw 10-20	0.0281	0.0002	0.1988
45	15/07/2014	15	37	Bw 10-20	0.0356	0.0003	0.2518
46	15/07/2014	15	37	Bw 20-30	0.0077	0.0001	0.0545
47	15/07/2014	15	37	Bw 20-30	0.0108	0.0001	0.0764
48	15/07/2014	15	37	Bw 20-30	0.0348	0.0002	0.2462
49	14/07/2014	15	35	Ap 0-5	0.1283	0.0009	0.9075
50	14/07/2014	15	35	Ap 0-5	0.1513	0.0011	1.0702
51	14/07/2014	15	35	Ap 0-5	0.4325	0.0031	3.0593
52	14/07/2014	15	35	Ap 5-10	0.0480	0.0003	0.3395
53	14/07/2014	15	35	Ap 5-10	0.0297	0.0002	0.2101
54	14/07/2014	15	35	Ap 5-10	0.0571	0.0004	0.4039
55	14/07/2014	15	35	Bw 10-20	0.0123	0.0001	0.0870
56	14/07/2014	15	35	Bw 10-20	0.0113	0.0001	0.0799
57	14/07/2014	15	35	Bw 10-20	0.0044	0.0000	0.0311
58	14/07/2014	15	35	Cu 20-30	0.0036	0.0000	0.0255
59	14/07/2014	15	35	Cu 20-30	0.0028	0.0000	0.0198
60	14/07/2014	15	35	Cu 20-30	0.0014	0.0000	0.0099
61	15/07/2014	14	147	Ap 0-5	0.2554	0.0018	1.8066
62	15/07/2014	14	147	Ap 0-5	0.1553	0.0011	1.0985
63	15/07/2014	14	147	Ap 0-5	0.1273	0.0009	0.9005
64	15/07/2014	14	147	Ap 5-10	0.0329	0.0002	0.2327
65	15/07/2014	14	147	Ap 5-10	0.0242	0.0002	0.1712
66	15/07/2014	14	147	Ap 5-10	0.0096	0.0001	0.0679
67	15/07/2014	14	147	Ap 10-20	0.0064	0.0000	0.0453
68	15/07/2014	14	147	Ap 10-20	0.0020	0.0000	0.0141
69	15/07/2014	14	147	Ap 10-20	0.0034	0.0000	0.0241
70	15/07/2014	14	147	Bw 22-30	0.0018	0.0000	0.0127
71	15/07/2014	14	147	Bw 22-30	0.0019	0.0000	0.0134
72	15/07/2014	14	147	Bw 22-30	0.0024	0.0000	0.0170
73	15/07/2014	14	149	Ap 0-5	0.2164	0.0015	1.5307
74	15/07/2014	14	149	Ap 0-5	0.4212	0.0030	2.9794
75	15/07/2014	14	149	Ap 0-5	0.5123	0.0036	3.6238
76	15/07/2014	14	149	Ap 5-10	0.1180	0.0008	0.8347

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
77	15/07/2014	14	149	Ap 5-10	0.1135	0.0008	0.8028
78	15/07/2014	14	149	Ap 5-10	0.1714	0.0012	1.2124
79	15/07/2014	14	149	Bw 10-22	0.0496	0.0004	0.3508
80	15/07/2014	14	149	Bw 10-22	0.0395	0.0003	0.2794
81	15/07/2014	14	149	Bw 10-22	0.0447	0.0003	0.3162
82	15/07/2014	14	149	Cu 22- 30	0.0259	0.0002	0.1832
83	15/07/2014	14	149	Cu 22- 30	0.0304	0.0002	0.2150
84	15/07/2014	14	149	Cu 22- 30	0.0274	0.0002	0.1938
85	15/07/2014	14	146	Ap 0-5	0.2824	0.0020	1.9976
86	15/07/2014	14	146	Ap 0-5	0.4417	0.0031	3.1244
87	15/07/2014	14	146	Ap 0-5	0.0453	0.0003	0.3204
88	15/07/2014	14	146	Ap 5-10	0.0913	0.0006	0.6458
89	15/07/2014	14	146	Ap 5-10	0.1711	0.0012	1.2103
90	15/07/2014	14	146	Ap 5-10	0.0856	0.0006	0.6055
91	15/07/2014	14	146	Ap2 10-15	0.0840	0.0006	0.5942
92	15/07/2014	14	146	Ap2 10-15	0.2613	0.0018	1.8483
93	15/07/2014	14	146	Ap2 10-15	0.0856	0.0006	0.6055
94	15/07/2014	14	146	Bw 15-28	0.0135	0.0001	0.0955
95	15/07/2014	14	146	Bw 15-28	0.0055	0.0000	0.0389
96	15/07/2014	14	146	Bw 15-28	0.0176	0.0001	0.1245
97	15/07/2014	14	148	Ap 0-5	0.3589	0.0025	2.5387
98	15/07/2014	14	148	Ap 0-5	0.6967	0.0049	4.9281
99	15/07/2014	14	148	Ap 0-5	0.4632	0.0033	3.2765
100	15/07/2014	14	148	Ap 5-10	0.0460	0.0003	0.3254
101	15/07/2014	14	148	Ap 5-10	0.0825	0.0006	0.5836
102	15/07/2014	14	148	Ap 5-10	0.1916	0.0014	1.3553
103	15/07/2014	14	148	Bw1 10-20	0.0768	0.0005	0.5432
104	15/07/2014	14	148	Bw1 10-20	0.0663	0.0005	0.4690
105	15/07/2014	14	148	Bw1 10-20	0.0606	0.0004	0.4287
106	15/07/2014	14	148	Bw2 20-30	0.0086	0.0001	0.0608
107	15/07/2014	14	148	Bw2 20-30	0.0285	0.0002	0.2016
108	15/07/2014	14	148	Bw2 20-30	0.0115	0.0001	0.0813
109	15/07/2014	14	125	Ap 0-5	0.2049	0.0014	1.4494
110	15/07/2014	14	125	Ap 0-5	0.2364	0.0017	1.6722
111	15/07/2014	14	125	Ap 0-5	0.1937	0.0014	1.3701
112	15/07/2014	14	125	Ap 5-10	0.0694	0.0005	0.4909
113	15/07/2014	14	125	Ap 5-10	0.1288	0.0009	0.9111
114	15/07/2014	14	125	Ap 5-10	0.0848	0.0006	0.5998
115	15/07/2014	14	125	Bw1 15-25	0.0495	0.0004	0.3501
116	15/07/2014	14	125	Bw1 15-25	0.0560	0.0004	0.3961
117	15/07/2014	14	125	Bw1 15-25	0.0358	0.0003	0.2532
118	15/07/2014	14	125	Bw2 25-30	0.0389	0.0003	0.2752
119	15/07/2014	14	125	Bw2 25-30	0.0450	0.0003	0.3183
120	15/07/2014	14	125	Bw2 25-30	0.0305	0.0002	0.2157
121	14/07/2014	11	A16	Ap 0-5	0.1931	0.0014	1.3659
122	14/07/2014	11	A16	Ap 0-5	0.1942	0.0014	1.3737
123	14/07/2014	11	A16	Ap 0-5	0.2340	0.0017	1.6552
124	14/07/2014	11	A16	Ap 5-10	0.0385	0.0003	0.2723
125	14/07/2014	11	A16	Ap 5-10	0.0954	0.0007	0.6748
126	14/07/2014	11	A16	Ap 5-10	0.0487	0.0003	0.3445
127	14/07/2014	11	A16	Ap 10-20	0.0388	0.0003	0.2745
128	14/07/2014	11	A16	Ap 10-20	0.0209	0.0001	0.1478
129	14/07/2014	11	A16	Ap 10-20	0.0122	0.0001	0.0863
130	14/07/2014	11	A16	Bw 20-30	0.0028	0.0000	0.0198
131	14/07/2014	11	A16	Bw 20-30	0.0026	0.0000	0.0184
132	14/07/2014	11	A16	Bw 20-30	0.0023	0.0000	0.0163
133	14/07/2014	15	17	Ap 0-5	0.0728	0.0005	0.5150

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
134	14/07/2014	15	17	Ap 0-5	0.0520	0.0004	0.3678
135	14/07/2014	15	17	Ap 0-5	0.2347	0.0017	1.6602
136	14/07/2014	15	17	Ap 5-10	0.0064	0.0000	0.0453
137	14/07/2014	15	17	Ap 5-10	0.0431	0.0003	0.3049
138	14/07/2014	15	17	Ap 5-10	0.0120	0.0001	0.0849
139	14/07/2014	15	17	Bw 10-20	0.0071	0.0001	0.0502
140	14/07/2014	15	17	Bw 10-20	0.0041	0.0000	0.0290
141	14/07/2014	15	17	Bw 10-20	0.0014	0.0000	0.0099
142	14/07/2014	15	17	bBw 20-30	0.0021	0.0000	0.0149
143	14/07/2014	15	17	bBw 20-30	0.0067	0.0000	0.0474
144	14/07/2014	15	17	bBw 20-30	0.0053	0.0000	0.0375
145	15/07/2014	9	31B	Ap 0-5	0.3392	0.0024	2.3994
146	15/07/2014	9	31B	Ap 0-5	0.2123	0.0015	1.5017
147	15/07/2014	9	31B	Ap 0-5	0.1804	0.0013	1.2761
148	15/07/2014	9	31B	Ap 5-10	0.1065	0.0008	0.7533
149	15/07/2014	9	31B	Ap 5-10	0.1866	0.0013	1.3199
150	15/07/2014	9	31B	Ap 5-10	0.1839	0.0013	1.3008
151	15/07/2014	9	31B	Bw 15-25	0.0525	0.0004	0.3714
152	15/07/2014	9	31B	Bw 15-25	0.0840	0.0006	0.5942
153	15/07/2014	9	31B	Bw 15-25	0.0594	0.0004	0.4202
154	15/07/2014	9	31B	Cu1 25-30	0.0024	0.0000	0.0170
155	15/07/2014	9	31B	Cu1 25-30	0.0116	0.0001	0.0821
156	15/07/2014	9	31B	Cu1 25-30	0.0033	0.0000	0.0233
157	16/07/2014	9	33	Ap 0-5	0.2594	0.0018	1.8349
158	16/07/2014	9	33	Ap 0-5	0.2674	0.0019	1.8915
159	16/07/2014	9	33	Ap 0-5	0.1689	0.0012	1.1947
160	16/07/2014	9	33	Ap 5-10	0.0628	0.0004	0.4442
161	16/07/2014	9	33	Ap 5-10	0.0977	0.0007	0.6911
162	16/07/2014	9	33	Ap 5-10	0.0978	0.0007	0.6918
163	16/07/2014	9	33	Bw 15-25	0.0542	0.0004	0.3834
164	16/07/2014	9	33	Bw 15-25	0.0291	0.0002	0.2058
165	16/07/2014	9	33	Bw 15-25	0.0380	0.0003	0.2688
166	16/07/2014	9	33	Cu1 25-30	0.0019	0.0000	0.0134
167	16/07/2014	9	33	Cu1 25-30	0.0086	0.0001	0.0608
168	16/07/2014	9	33	Cu1 25-30	0.0108	0.0001	0.0764
169	15/07/2014	9	32A	Ap 0-5	0.1426	0.0010	1.0087
170	15/07/2014	9	32A	Ap 0-5	0.1675	0.0012	1.1848
171	15/07/2014	9	32A	Ap 0-5	0.2540	0.0018	1.7967
172	15/07/2014	9	32A	Ap 5-10	0.0535	0.0004	0.3784
173	15/07/2014	9	32A	Ap 5-10	0.0825	0.0006	0.5836
174	15/07/2014	9	32A	Ap 5-10	0.1568	0.0011	1.1091
175	15/07/2014	9	32A	Ap 10-20	0.0502	0.0004	0.3551
176	15/07/2014	9	32A	Ap 10-20	0.0506	0.0004	0.3579
177	15/07/2014	9	32A	Ap 10-20	0.0644	0.0005	0.4555
178	15/07/2014	9	32A	Bw 20-25	0.0009	0.0000	0.0064
179	15/07/2014	9	32A	Bw 20-25	0.0014	0.0000	0.0099
180	15/07/2014	9	32A	Bw 20-25	0.0076	0.0001	0.0538

Spring

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
1	8/10/2014	15	8	Ap 0-5	0.2512	0.0018	1.7769
2	8/10/2014	15	8	Ap 0-5	0.1420	0.0010	1.0044
3	8/10/2014	15	8	Ap 0-5	0.1543	0.0011	1.0915
4	8/10/2014	15	8	Ap 5-10	0.1223	0.0009	0.8651
5	8/10/2014	15	8	Ap 5-10	0.2529	0.0018	1.7889
6	8/10/2014	15	8	Ap 5-10	0.1291	0.0009	0.9132
7	8/10/2014	15	8	Bw 10-20	0.0452	0.0003	0.3197
8	8/10/2014	15	8	Bw 10-20	0.0058	0.0000	0.0410
9	8/10/2014	15	8	Bw 10-20	0.0262	0.0002	0.1853
10	8/10/2014	15	8	Bah 20-30	0.0116	0.0001	0.0821
11	8/10/2014	15	8	Bah 20-30	0.0144	0.0001	0.1019
12	8/10/2014	15	8	Bah 20-30	0.0342	0.0002	0.2419
13	8/10/2014	15	15	Ap 0-5	0.1565	0.0011	1.1070
14	8/10/2014	15	15	Ap 0-5	0.3302	0.0023	2.3357
15	8/10/2014	15	15	Ap 0-5	0.1176	0.0008	0.8319
16	8/10/2014	15	15	Ap 5-10	0.0704	0.0005	0.4980
17	8/10/2014	15	15	Ap 5-10	0.0691	0.0005	0.4888
18	8/10/2014	15	15	Ap 5-10	0.0490	0.0003	0.3466
19	8/10/2014	15	15	Bw 10-20	0.0402	0.0003	0.2844
20	8/10/2014	15	15	Bw 10-20	0.0037	0.0000	0.0262
21	8/10/2014	15	15	Bw 10-20	0.0207	0.0001	0.1464
22	8/10/2014	15	15	Cu 20-30	0.0102	0.0001	0.0722
23	8/10/2014	15	15	Cu 20-30	0.0099	0.0001	0.0700
24	8/10/2014	15	15	Cu 20-30	0.0072	0.0001	0.0509
25	8/10/2014	11	B12	Ap 0-5	0.5253	0.0037	3.7157
26	8/10/2014	11	B12	Ap 0-5	0.4974	0.0035	3.5184
27	8/10/2014	11	B12	Ap 0-5	0.4254	0.0030	3.0091
28	8/10/2014	11	B12	Ap 5-10	0.1154	0.0008	0.8163
29	8/10/2014	11	B12	Ap 5-10	0.1138	0.0008	0.8050
30	8/10/2014	11	B12	Ap 5-10	0.1263	0.0009	0.8934
31	8/10/2014	11	B12	Bw 10-20	0.0475	0.0003	0.3360
32	8/10/2014	11	B12	Bw 10-20	0.0596	0.0004	0.4216
33	8/10/2014	11	B12	Bw 10-20	0.0434	0.0003	0.3070
34	8/10/2014	11	B12	Cu1 20-30	0.0181	0.0001	0.1280
35	8/10/2014	11	B12	Cu1 20-30	0.0038	0.0000	0.0269
36	8/10/2014	11	B12	Cu1 20-30	0.0020	0.0000	0.0141
37	8/10/2014	15	37	Ap 0-5	0.2779	0.0020	1.9657
38	8/10/2014	15	37	Ap 0-5	0.3465	0.0025	2.4510
39	8/10/2014	15	37	Ap 0-5	0.1776	0.0013	1.2563
40	8/10/2014	15	37	Ap 5-10	0.0874	0.0006	0.6182
41	8/10/2014	15	37	Ap 5-10	0.0910	0.0006	0.6437
42	8/10/2014	15	37	Ap 5-10	0.0643	0.0005	0.4548
43	8/10/2014	15	37	Bw 10-20	0.0250	0.0002	0.1768
44	8/10/2014	15	37	Bw 10-20	0.0131	0.0001	0.0927
45	8/10/2014	15	37	Bw 10-20	0.0210	0.0001	0.1485
46	8/10/2014	15	37	Bw 20-30	0.0085	0.0001	0.0601
47	8/10/2014	15	37	Bw 20-30	0.0292	0.0002	0.2065
48	8/10/2014	15	37	Bw 20-30	0.0143	0.0001	0.1012
49	8/10/2014	15	35	Ap 0-5	0.4743	0.0034	3.3550
50	8/10/2014	15	35	Ap 0-5	0.5668	0.0040	4.0093
51	8/10/2014	15	35	Ap 0-5	0.3543	0.0025	2.5062
52	8/10/2014	15	35	Ap 5-10	0.0507	0.0004	0.3586
53	8/10/2014	15	35	Ap 5-10	0.0973	0.0007	0.6883
54	8/10/2014	15	35	Ap 5-10	0.1368	0.0010	0.9677
55	8/10/2014	15	35	Bw 10-20	0.0256	0.0002	0.1811
56	8/10/2014	15	35	Bw 10-20	0.0553	0.0004	0.3912

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
57	8/10/2014	15	35	Bw 10-20	0.0212	0.0001	0.1500
58	8/10/2014	15	35	Cu 20-30	0.0187	0.0001	0.1323
59	8/10/2014	15	35	Cu 20-30	0.0059	0.0000	0.0417
60	8/10/2014	15	35	Cu 20-30	0.0192	0.0001	0.1358
61	9/10/2014	14	147	Ap 0-5	0.1787	0.0013	1.2640
62	9/10/2014	14	147	Ap 0-5	0.5241	0.0037	3.7073
63	9/10/2014	14	147	Ap 0-5	0.7616	0.0054	5.3872
64	9/10/2014	14	147	Ap 5-10	0.1781	0.0013	1.2598
65	9/10/2014	14	147	Ap 5-10	0.1501	0.0011	1.0617
66	9/10/2014	14	147	Ap 5-10	0.2339	0.0017	1.6545
67	9/10/2014	14	147	Ap 10-20	0.0476	0.0003	0.3367
68	9/10/2014	14	147	Ap 10-20	0.0941	0.0007	0.6656
69	9/10/2014	14	147	Ap 10-20	0.0593	0.0004	0.4195
70	9/10/2014	14	147	Bw 22-30	0.0050	0.0000	0.0354
71	9/10/2014	14	147	Bw 22-30	0.0237	0.0002	0.1676
72	9/10/2014	14	147	Bw 22-30	0.0059	0.0000	0.0417
73	9/10/2014	14	149	Ap 0-5	0.1666	0.0012	1.1785
74	9/10/2014	14	149	Ap 0-5	0.4045	0.0029	2.8613
75	9/10/2014	14	149	Ap 0-5	0.1743	0.0012	1.2329
76	9/10/2014	14	149	Ap 5-10	0.2666	0.0019	1.8858
77	9/10/2014	14	149	Ap 5-10	0.0800	0.0006	0.5659
78	9/10/2014	14	149	Ap 5-10	0.4624	0.0033	3.2708
79	9/10/2014	14	149	Bw 10-22	0.0267	0.0002	0.1889
80	9/10/2014	14	149	Bw 10-22	0.0341	0.0002	0.2412
81	9/10/2014	14	149	Bw 10-22	0.0402	0.0003	0.2844
82	9/10/2014	14	149	Cu 22- 30	0.0189	0.0001	0.1337
83	9/10/2014	14	149	Cu 22- 30	0.0073	0.0001	0.0516
84	9/10/2014	14	149	Cu 22- 30	0.0147	0.0001	0.1040
85	9/10/2014	14	146	Ap 0-5	0.4853	0.0034	3.4328
86	9/10/2014	14	146	Ap 0-5	0.3239	0.0023	2.2911
87	9/10/2014	14	146	Ap 0-5	0.3426	0.0024	2.4234
88	9/10/2014	14	146	Ap 5-10	0.1024	0.0007	0.7243
89	9/10/2014	14	146	Ap 5-10	0.0662	0.0005	0.4683
90	9/10/2014	14	146	Ap 5-10	0.0676	0.0005	0.4782
91	9/10/2014	14	146	Ap2 10-15	0.0421	0.0003	0.2978
92	9/10/2014	14	146	Ap2 10-15	0.0282	0.0002	0.1995
93	9/10/2014	14	146	Ap2 10-15	0.0221	0.0002	0.1563
94	9/10/2014	14	146	Bw 15-28	0.0228	0.0002	0.1613
95	9/10/2014	14	146	Bw 15-28	0.0146	0.0001	0.1033
96	9/10/2014	14	146	Bw 15-28	0.0181	0.0001	0.1280
97	9/10/2014	14	148	Ap 0-5	0.6672	0.0047	4.7195
98	9/10/2014	14	148	Ap 0-5	0.6614	0.0047	4.6785
99	9/10/2014	14	148	Ap 0-5	0.5767	0.0041	4.0793
100	9/10/2014	14	148	Ap 5-10	0.0817	0.0006	0.5779
101	9/10/2014	14	148	Ap 5-10	0.1846	0.0013	1.3058
102	9/10/2014	14	148	Ap 5-10	0.0808	0.0006	0.5715
103	9/10/2014	14	148	Bw1 10-20	0.0373	0.0003	0.2638
104	9/10/2014	14	148	Bw1 10-20	0.0386	0.0003	0.2730
105	9/10/2014	14	148	Bw1 10-20	0.0370	0.0003	0.2617
106	9/10/2014	14	148	Bw2 20-30	0.0055	0.0000	0.0389
107	9/10/2014	14	148	Bw2 20-30	0.0178	0.0001	0.1259
108	9/10/2014	14	148	Bw2 20-30	0.0234	0.0002	0.1655
109	9/10/2014	14	125	Ap 0-5	0.4669	0.0033	3.3026
110	9/10/2014	14	125	Ap 0-5	0.9365	0.0066	6.6244
111	9/10/2014	14	125	Ap 0-5	0.8848	0.0063	6.2587
112	9/10/2014	14	125	Ap 5-10	0.2133	0.0015	1.5088
113	9/10/2014	14	125	Ap 5-10	0.1429	0.0010	1.0108

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
114	9/10/2014	14	125	Ap 5-10	0.1674	0.0012	1.1841
115	9/10/2014	14	125	Bw1 15-25	0.0413	0.0003	0.2921
116	9/10/2014	14	125	Bw1 15-25	0.1050	0.0007	0.7427
117	9/10/2014	14	125	Bw1 15-25	0.1042	0.0007	0.7371
118	9/10/2014	14	125	Bw2 25-30	0.0060	0.0000	0.0424
119	9/10/2014	14	125	Bw2 25-30	0.0445	0.0003	0.3148
120	9/10/2014	14	125	Bw2 25-30	0.0487	0.0003	0.3445
121	8/10/2014	11	A16	Ap 0-5	0.4270	0.0030	3.0204
122	8/10/2014	11	A16	Ap 0-5	0.0662	0.0005	0.4683
123	8/10/2014	11	A16	Ap 0-5	0.5420	0.0038	3.8339
124	8/10/2014	11	A16	Ap 5-10	0.0572	0.0004	0.4046
125	8/10/2014	11	A16	Ap 5-10	0.0880	0.0006	0.6225
126	8/10/2014	11	A16	Ap 5-10	0.0633	0.0004	0.4478
127	8/10/2014	11	A16	Ap 10-20	0.0137	0.0001	0.0969
128	8/10/2014	11	A16	Ap 10-20	0.0112	0.0001	0.0792
129	8/10/2014	11	A16	Ap 10-20	0.0170	0.0001	0.1203
130	8/10/2014	11	A16	Bw 20-30	0.0109	0.0001	0.0771
131	8/10/2014	11	A16	Bw 20-30	0.0122	0.0001	0.0863
132	8/10/2014	11	A16	Bw 20-30	0.0026	0.0000	0.0184
133	8/10/2014	15	17	Ap 0-5	0.5027	0.0036	3.5559
134	8/10/2014	15	17	Ap 0-5	0.5003	0.0035	3.5389
135	8/10/2014	15	17	Ap 0-5	0.2643	0.0019	1.8695
136	8/10/2014	15	17	Ap 5-10	0.0674	0.0005	0.4768
137	8/10/2014	15	17	Ap 5-10	0.0805	0.0006	0.5694
138	8/10/2014	15	17	Ap 5-10	0.3769	0.0027	2.6660
139	8/10/2014	15	17	Bw 10-20	0.0692	0.0005	0.4895
140	8/10/2014	15	17	Bw 10-20	0.0156	0.0001	0.1103
141	8/10/2014	15	17	Bw 10-20	0.0718	0.0005	0.5079
142	8/10/2014	15	17	bBw 20-30	0.0020	0.0000	0.0141
143	8/10/2014	15	17	bBw 20-30	0.0196	0.0001	0.1386
144	8/10/2014	15	17	bBw 20-30	0.0122	0.0001	0.0863
145	9/10/2014	9	31B	Ap 0-5	0.1899	0.0013	1.3433
146	9/10/2014	9	31B	Ap 0-5	0.5037	0.0036	3.5630
147	9/10/2014	9	31B	Ap 0-5	0.2305	0.0016	1.6305
148	9/10/2014	9	31B	Ap 5-10	0.1372	0.0010	0.9705
149	9/10/2014	9	31B	Ap 5-10	0.0960	0.0007	0.6791
150	9/10/2014	9	31B	Ap 5-10	0.0911	0.0006	0.6444
151	9/10/2014	9	31B	Bw 15-25	0.0142	0.0001	0.1004
152	9/10/2014	9	31B	Bw 15-25	0.0175	0.0001	0.1238
153	9/10/2014	9	31B	Bw 15-25	0.0200	0.0001	0.1415
154	9/10/2014	9	31B	Cu1 25-30	0.0039	0.0000	0.0276
155	9/10/2014	9	31B	Cu1 25-30	0.0084	0.0001	0.0594
156	9/10/2014	9	31B	Cu1 25-30	0.0060	0.0000	0.0424
157	9/10/2014	9	33	Ap 0-5	0.4999	0.0035	3.5361
158	9/10/2014	9	33	Ap 0-5	0.3738	0.0026	2.6441
159	9/10/2014	9	33	Ap 0-5	0.4352	0.0031	3.0784
160	9/10/2014	9	33	Ap 5-10	0.1488	0.0011	1.0525
161	9/10/2014	9	33	Ap 5-10	0.0741	0.0005	0.5242
162	9/10/2014	9	33	Ap 5-10	0.0721	0.0005	0.5100
163	9/10/2014	9	33	Bw 15-25	0.0526	0.0004	0.3721
164	9/10/2014	9	33	Bw 15-25	0.0297	0.0002	0.2101
165	9/10/2014	9	33	Bw 15-25	0.0498	0.0004	0.3523
166	9/10/2014	9	33	Cu1 25-30	0.0034	0.0000	0.0241
167	9/10/2014	9	33	Cu1 25-30	0.0375	0.0003	0.2653
168	9/10/2014	9	33	Cu1 25-30	0.0318	0.0002	0.2249
169	9/10/2014	9	32A	Ap 0-5	0.2078	0.0015	1.4699
170	9/10/2014	9	32A	Ap 0-5	0.0938	0.0007	0.6635

Sample number	Date sampled	Farm	Pdk	Horizon - depth	Root dry weight	Dry root density (g/cm^3)	Dry root density (mg/cm^3)
171	9/10/2014	9	32A	Ap 0-5	0.2150	0.0015	1.5208
172	9/10/2014	9	32A	Ap 5-10	0.0229	0.0002	0.1620
173	9/10/2014	9	32A	Ap 5-10	0.0208	0.0001	0.1471
174	9/10/2014	9	32A	Ap 5-10	0.0314	0.0002	0.2221
175	9/10/2014	9	32A	Ap 10-20	0.0397	0.0003	0.2808
176	9/10/2014	9	32A	Ap 10-20	0.0323	0.0002	0.2285
177	9/10/2014	9	32A	Ap 10-20	0.0214	0.0002	0.1514
178	9/10/2014	9	32A	Bw 20-25	0.0024	0.0000	0.0170
179	9/10/2014	9	32A	Bw 20-25	0.0015	0.0000	0.0106
180	9/10/2014	9	32A	Bw 20-25	0.0225	0.0002	0.1592

Appendix 7 – Soil Macrofauna

Summer

Sampling Date	Farm	Paddock	Grass grub	Black beetle	Earthworms
13-01-14	15	8	0	0	0
21-01-14	15	15	0	0	0
22-01-14	11	B12	1	0	2
22-01-14	15	37	0	0	12
22-01-14	15	35	0	0	1
23-01-14	14	147	0	0	0
23-01-14	14	149	0	0	1
22-01-14	14	146	3	0	0
23-01-14	14	148	0	0	4
23-01-14	14	125	0	0	0
23-01-14	11	A16	0	0	0
22-01-14	15	17	0	0	2
24-01-14	9	31B	0	0	0
24-01-14	9	33	1	0	1
24-01-14	9	32A	0	0	0

Autumn

Sampling Date	Farm	Paddock	Grass grub	Black beetle	Earthworms
07-04-14	15	8	0	0	0
07-04-14	15	15	0	0	0
07-04-14	11	B12	2	0	0
07-04-14	15	37	0	0	4
07-04-14	15	35	0	0	0
08-04-14	14	147	0	0	0
08-04-14	14	149	0	0	3
08-04-14	14	146	0	0	0
08-04-14	14	148	0	0	0
08-04-14	14	125	0	0	0
07-04-14	11	A16	0	0	0
08-04-14	15	17	0	0	0
08-04-14	9	31B	0	0	0
08-04-14	9	33	2	0	1
08-04-14	9	32A	1	0	0

Winter

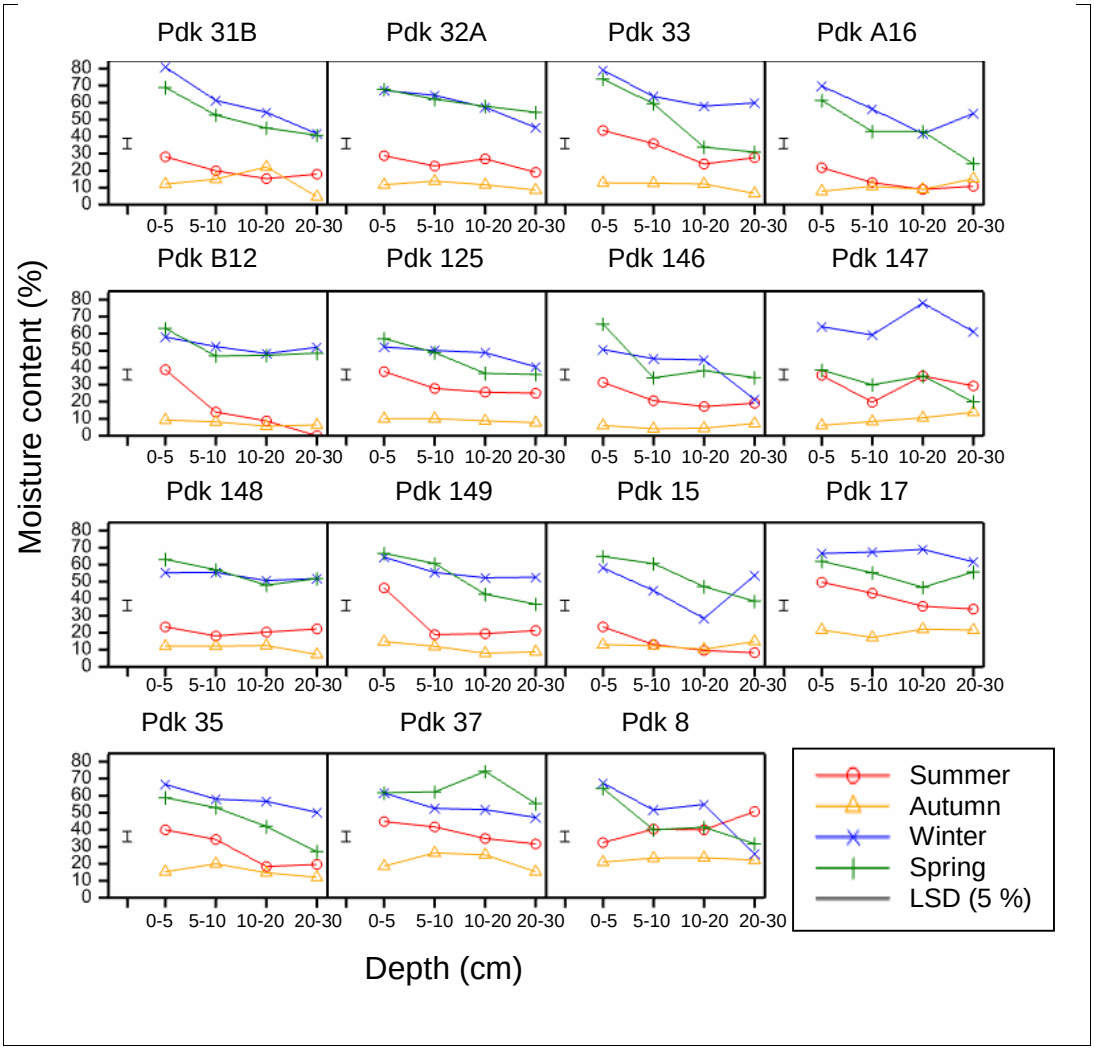
Sampling Date	Farm	Paddock	Grass grub	Black beetle	Earthworms
14-07-14	15	8	0	0	10
14-07-14	15	15	0	0	14
14-07-14	11	B12	0	0	10
15-07-14	15	37	0	0	5
14-07-14	15	35	0	0	3
15-07-14	14	147	0	0	0
15-07-14	14	149	0	0	2
15-07-14	14	146	1	0	10
15-07-14	14	148	2	0	8
15-07-14	14	125	0	0	8
14-07-14	11	A16	0	0	6
14-07-14	15	17	2	0	11
15-07-14	9	31B	0	0	3
16-07-14	9	33	0	0	8
15-07-14	9	32A	1	0	5

Spring

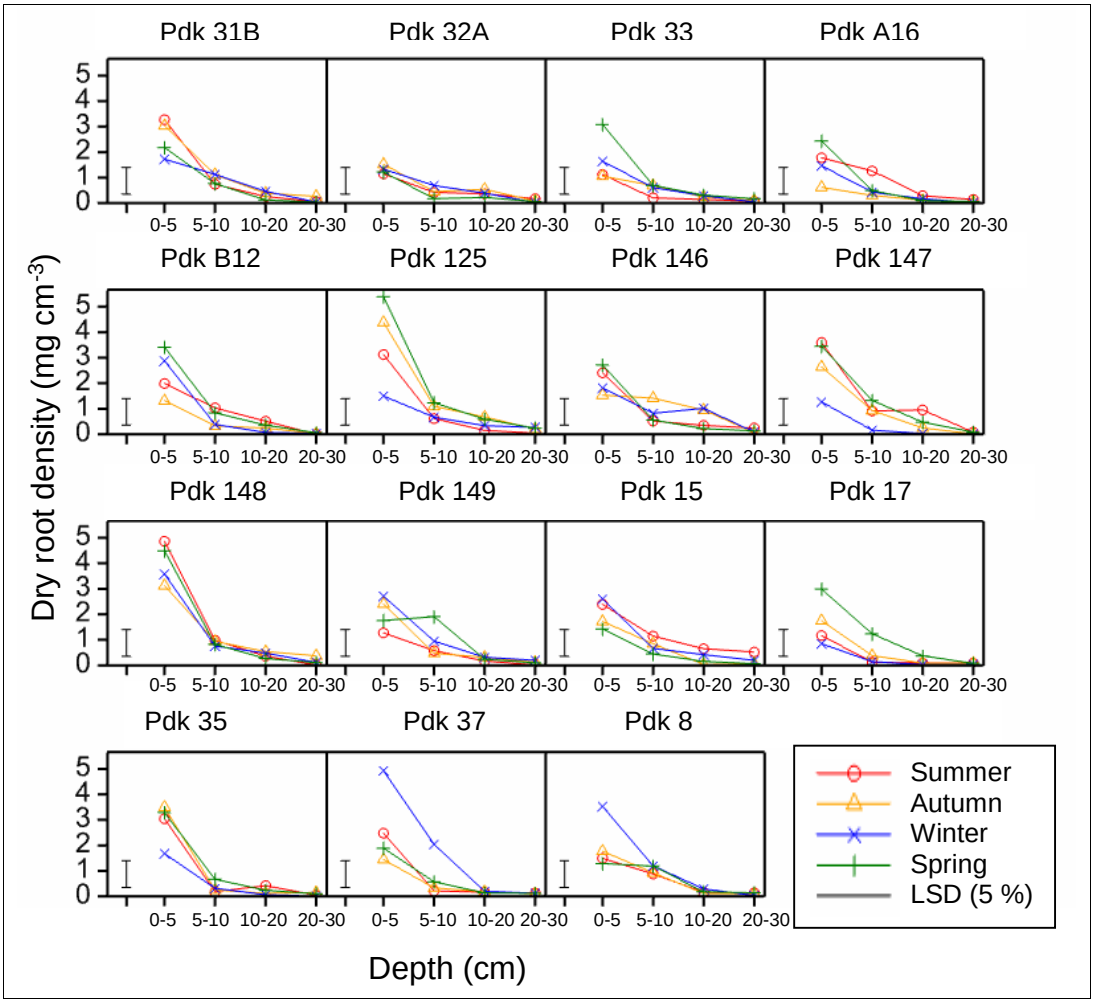
Sampling Date	Farm	Paddock	Grass grub	Black beetle	Earthworms
08-10-14	15	8	0	0	4
08-10-14	15	15	0	0	1
08-10-14	11	B12	1	0	5
08-10-14	15	37	0	0	26
08-10-14	15	35	0	0	1
09-10-14	14	147	0	0	3
09-10-14	14	149	0	0	8
09-10-14	14	146	0	0	1
09-10-14	14	148	0	0	7
09-10-14	14	125	0	0	10
08-10-14	11	A16	1	0	14
09-10-14	15	17	0	0	6
09-10-14	9	31B	0	0	2
09-10-14	9	33	0	0	10
09-10-14	9	32A	1	0	5

Appendix 8 – Extra Graphs

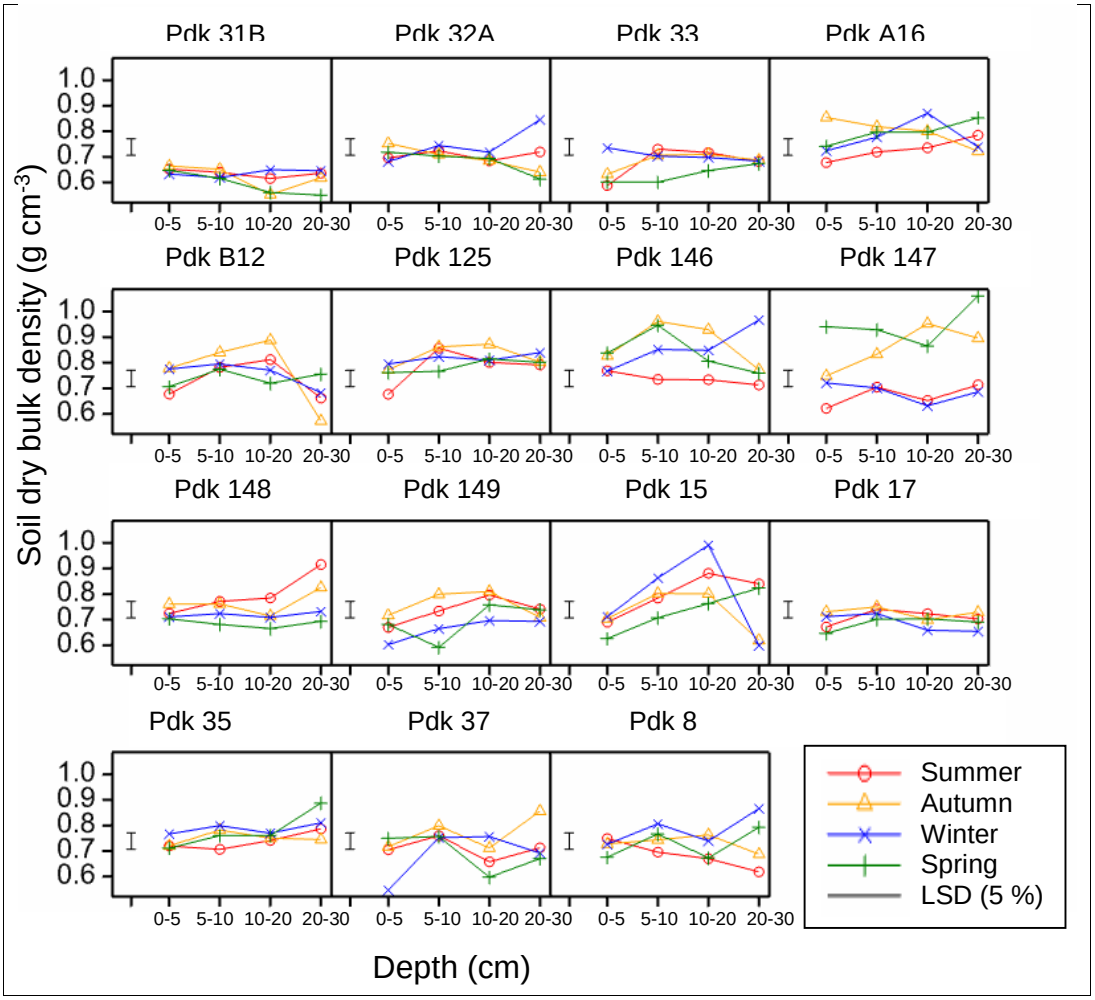
Moisture content



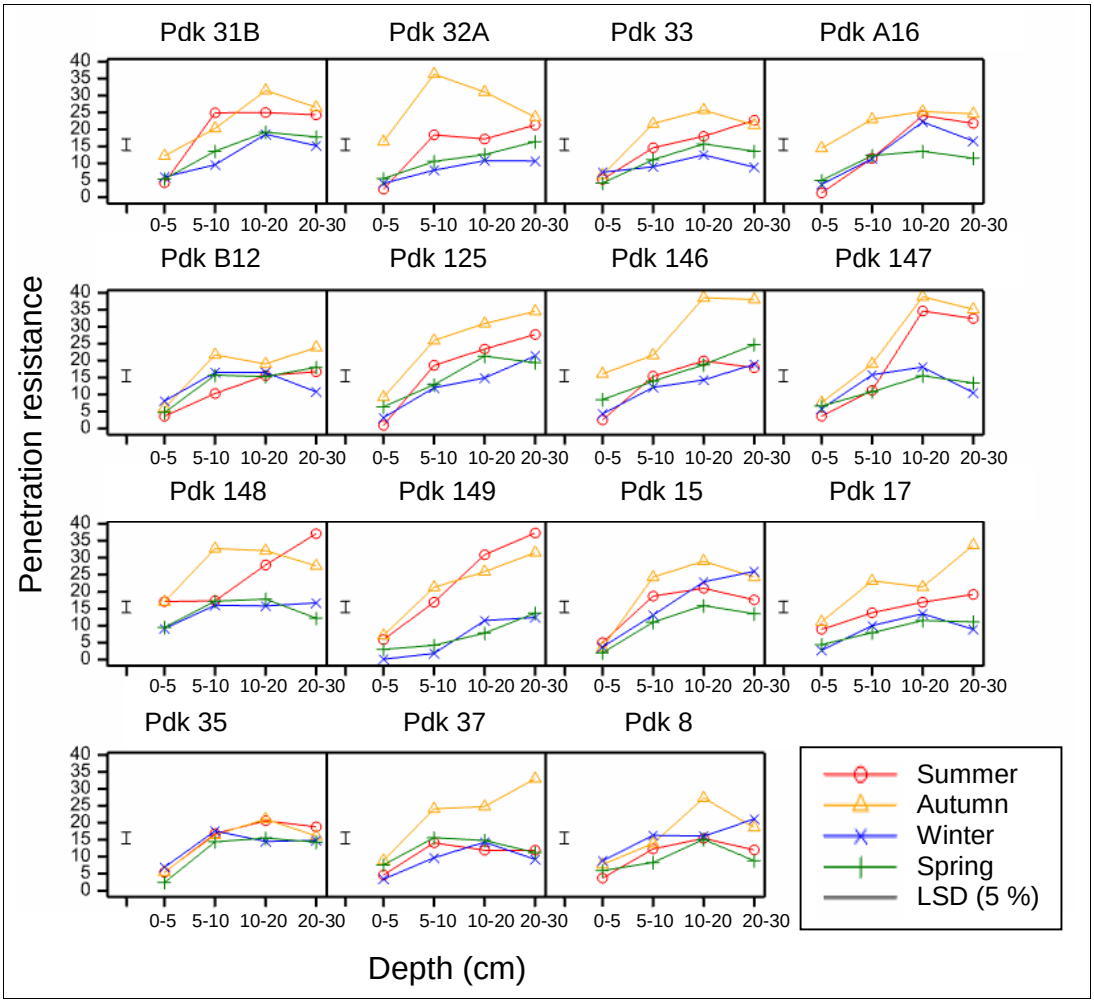
Dry root density



Soil Dry Bulk Density

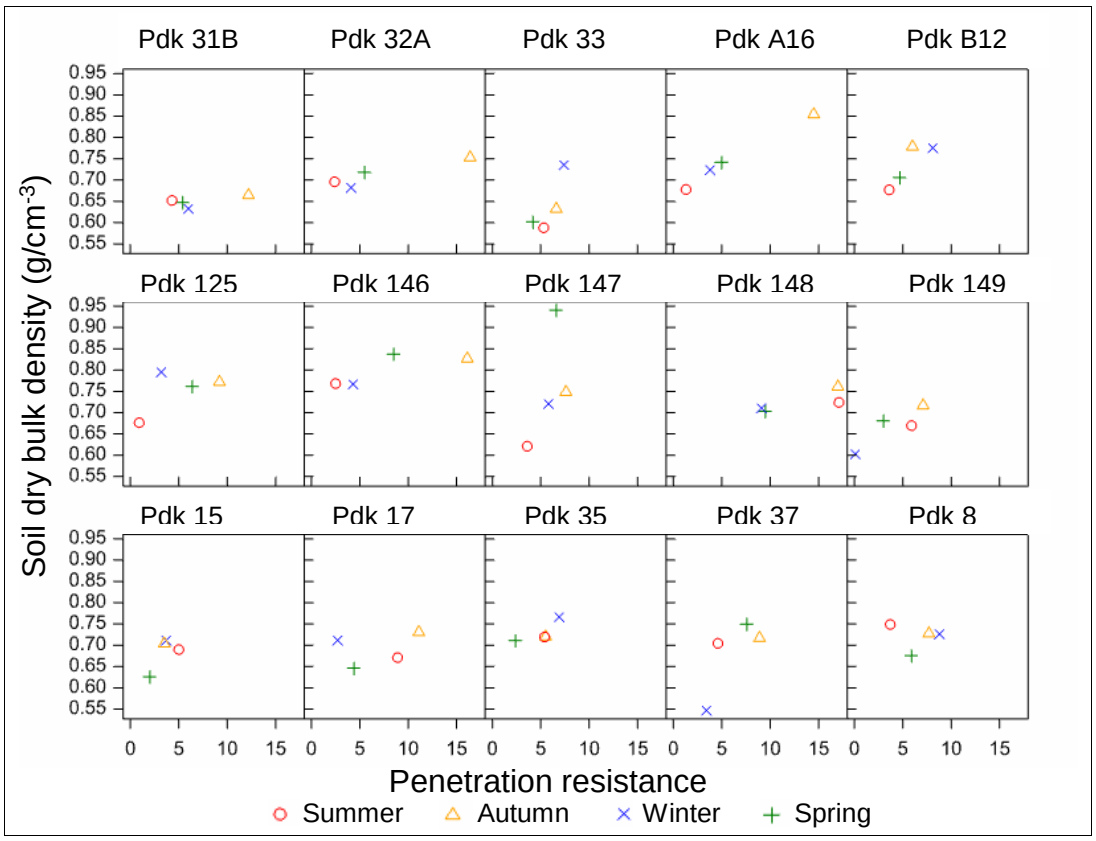


Penetration Resistance

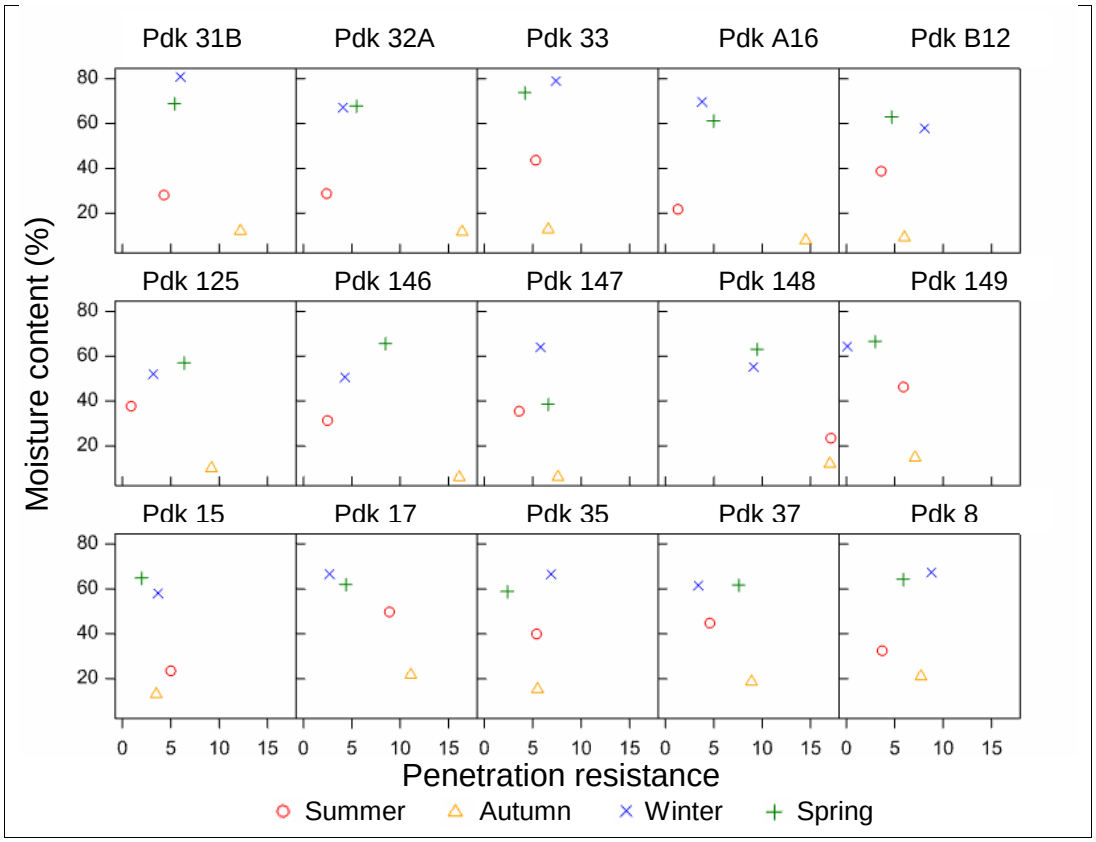


Trellis plots for significant relationships between soil variables

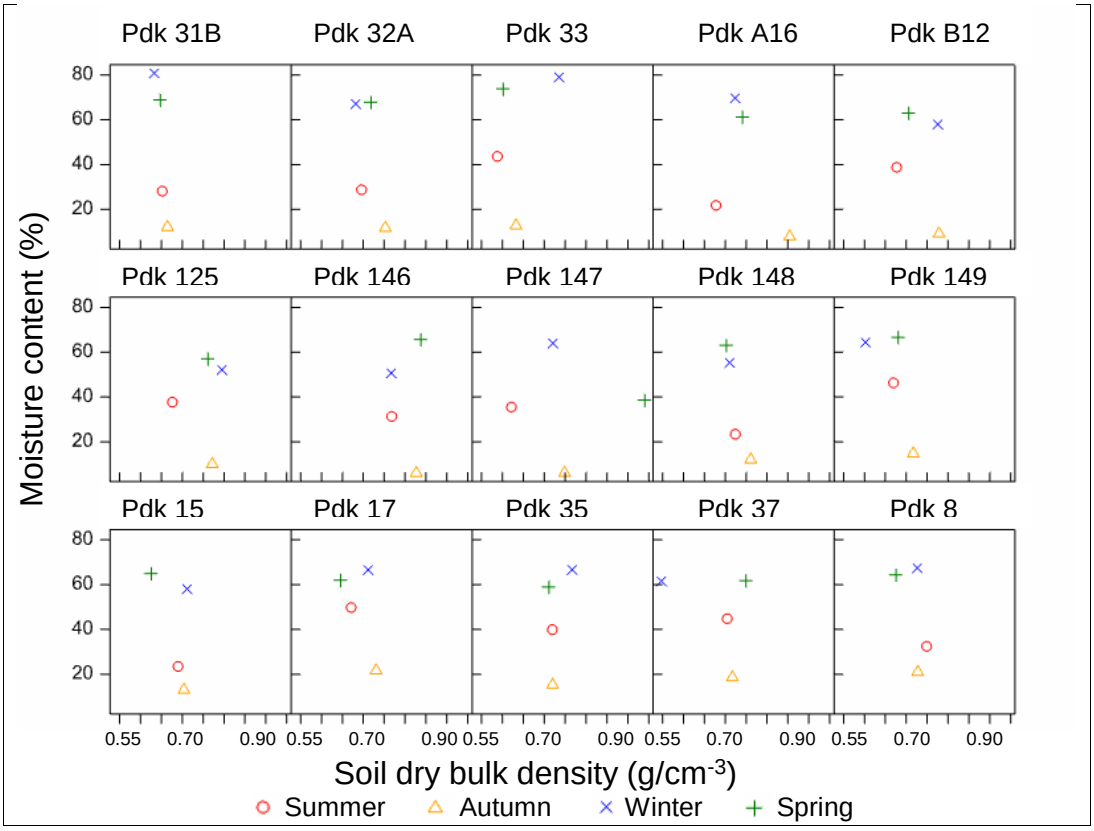
Soil dry bulk density and penetration resistance – 0-5 cm depth



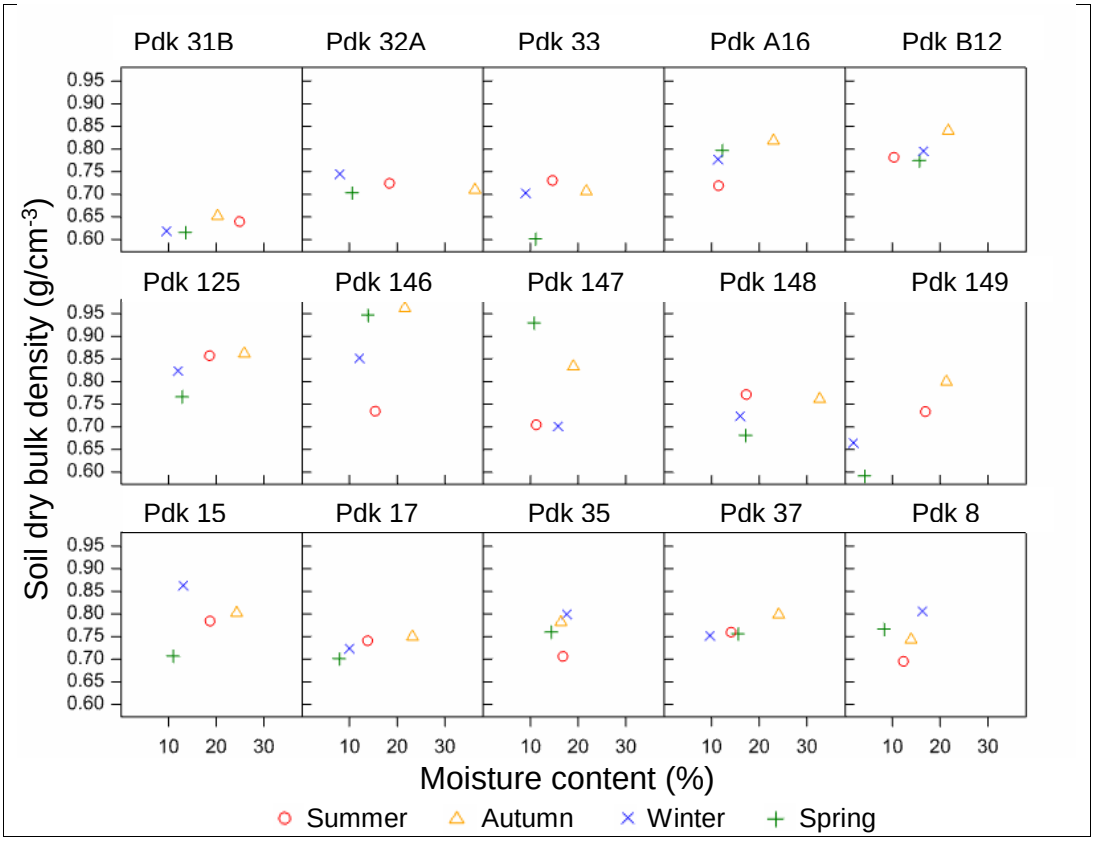
Moisture content and penetration resistance – 0-5 cm depth



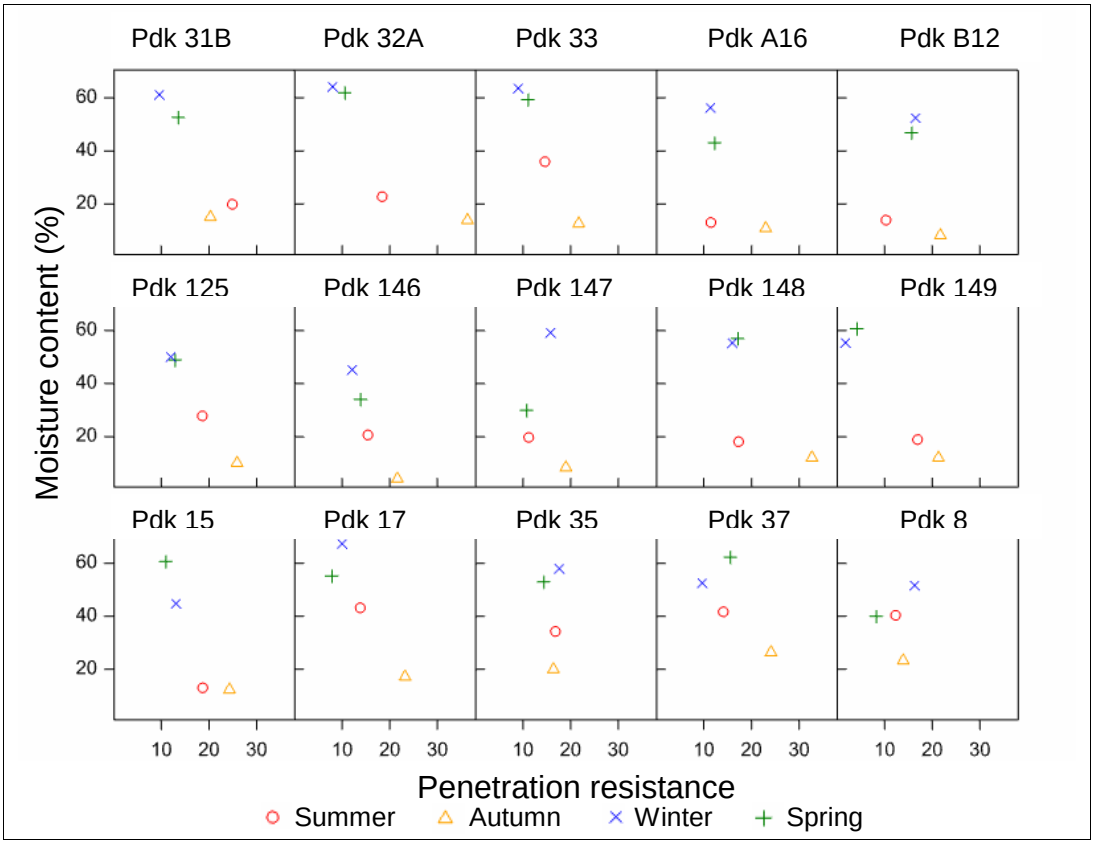
Moisture content and soil dry bulk density – 0-5 cm depth



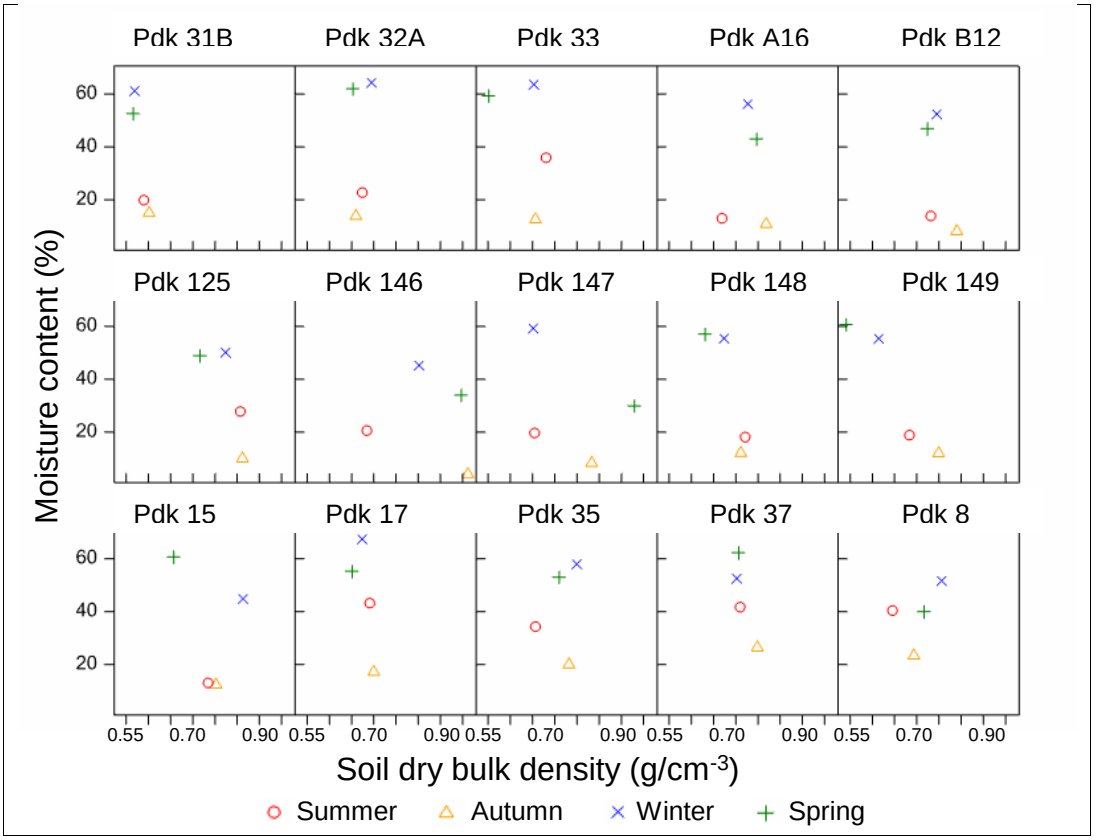
Soil dry bulk density and penetration resistance – 5-10 cm depth



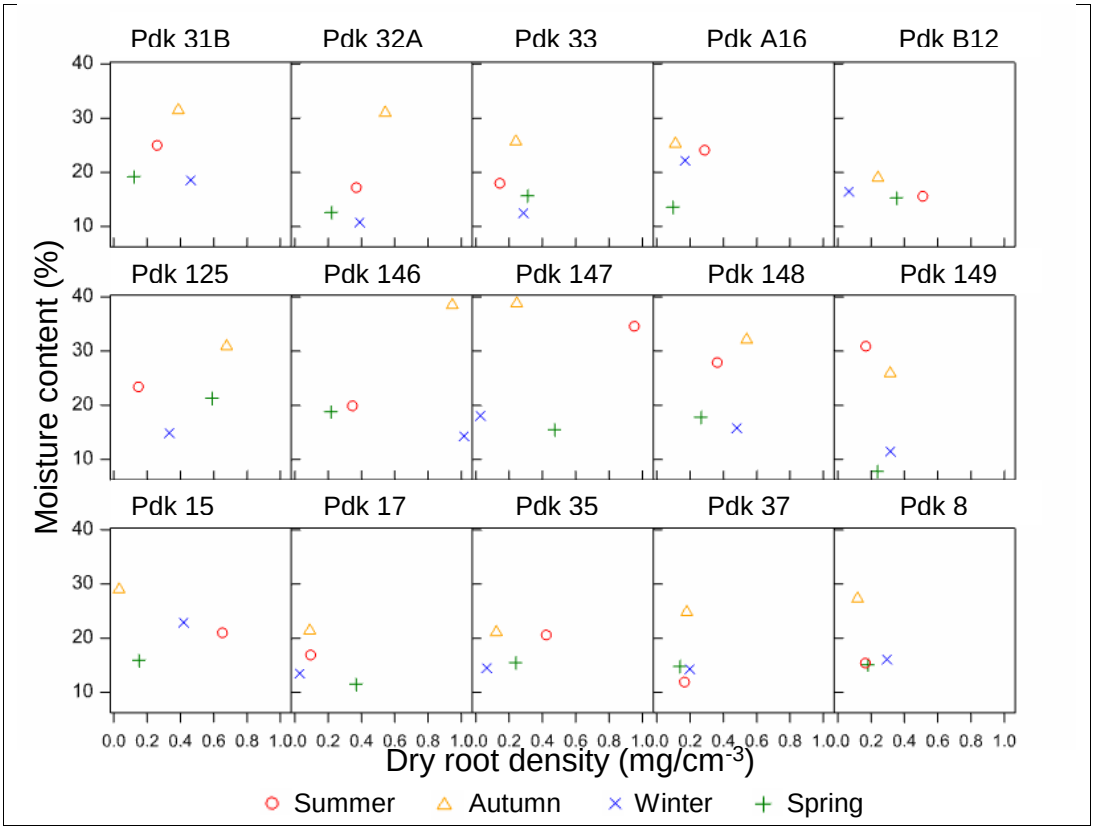
Moisture content and penetration resistance – 5-10 cm depth



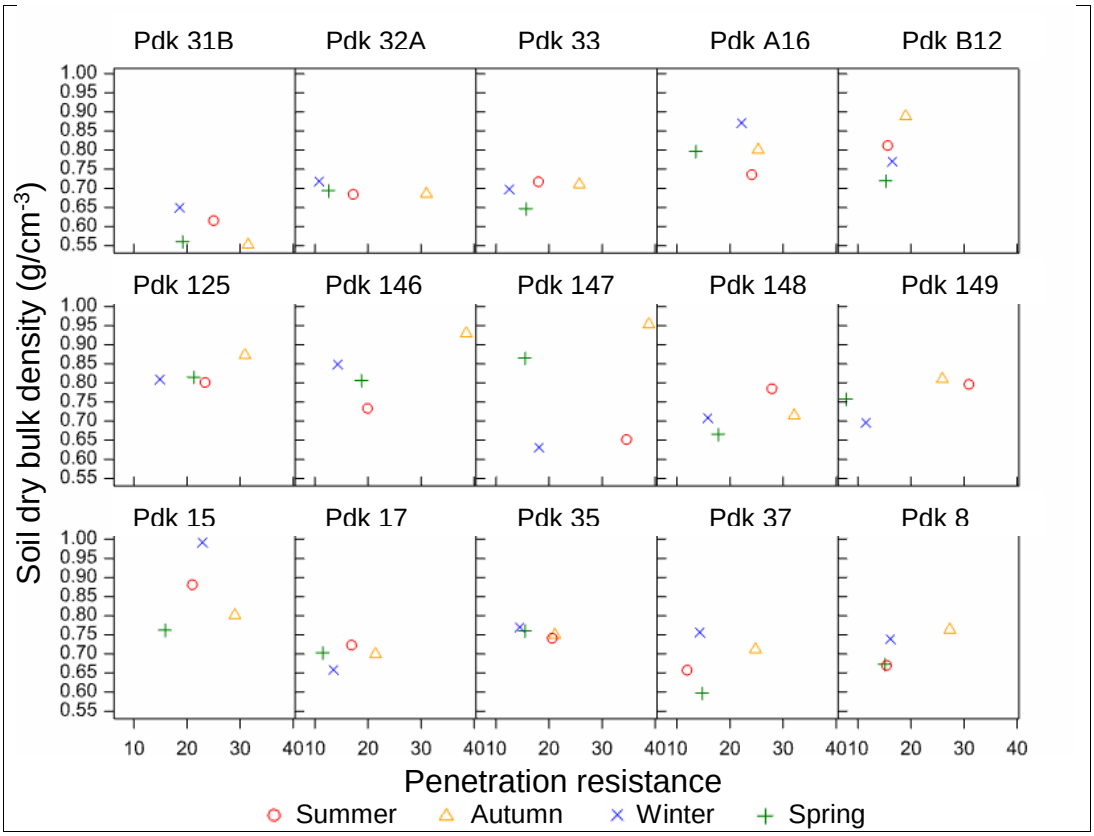
Moisture content and soil dry bulk density – 5-10 cm depth



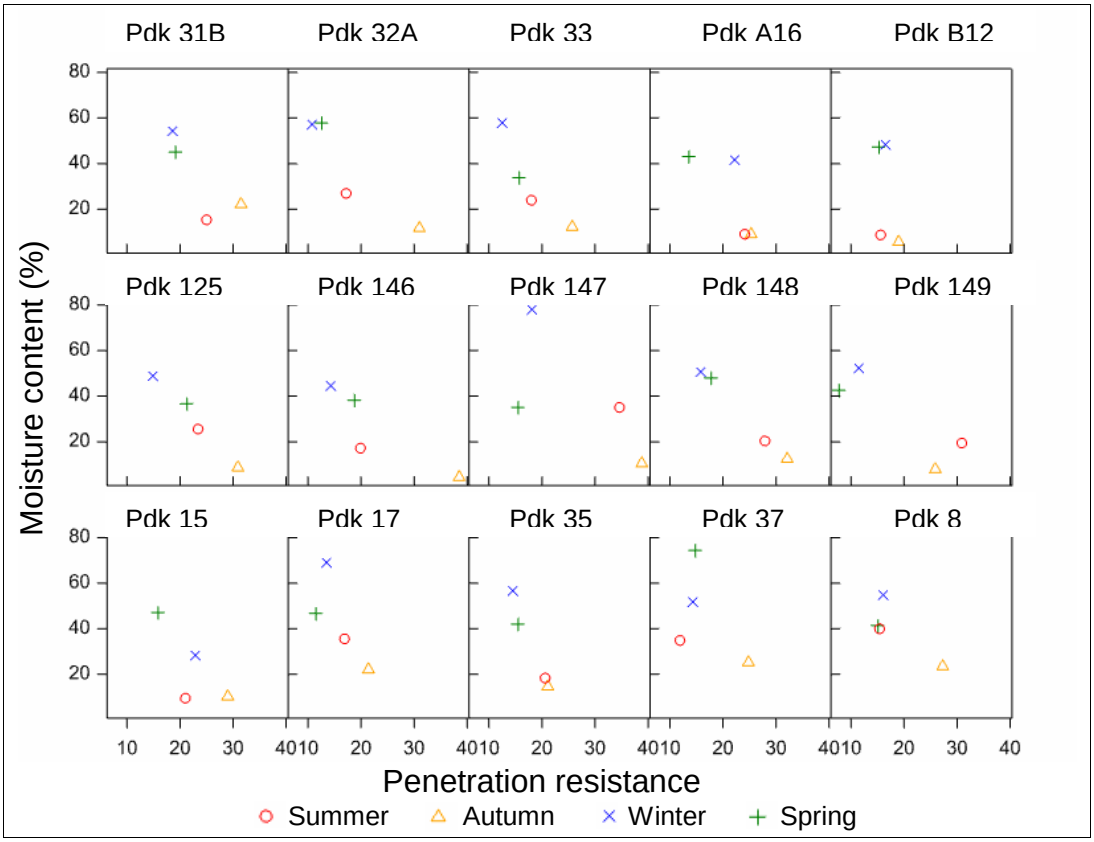
Penetration resistance and dry root density – 10-20 cm depth



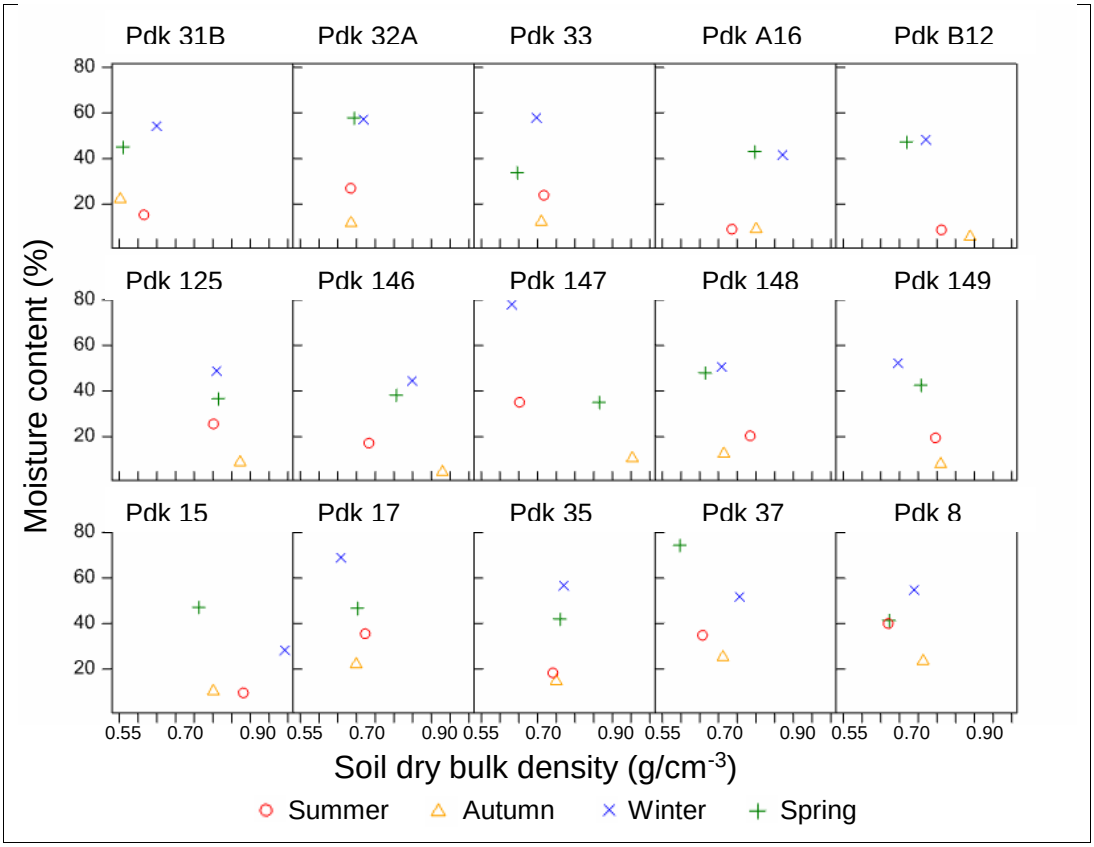
Soil dry bulk density and penetration resistance – 10-20 cm depth



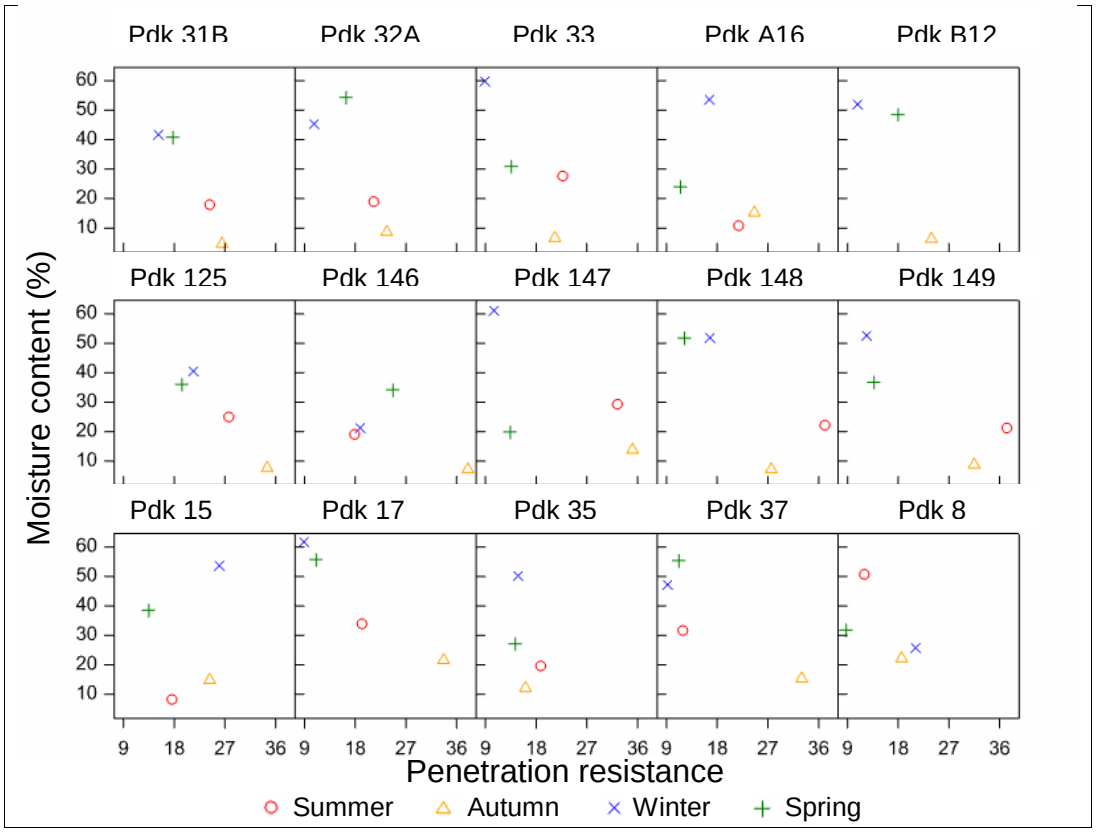
Moisture content and penetration resistance – 10-20 cm depth



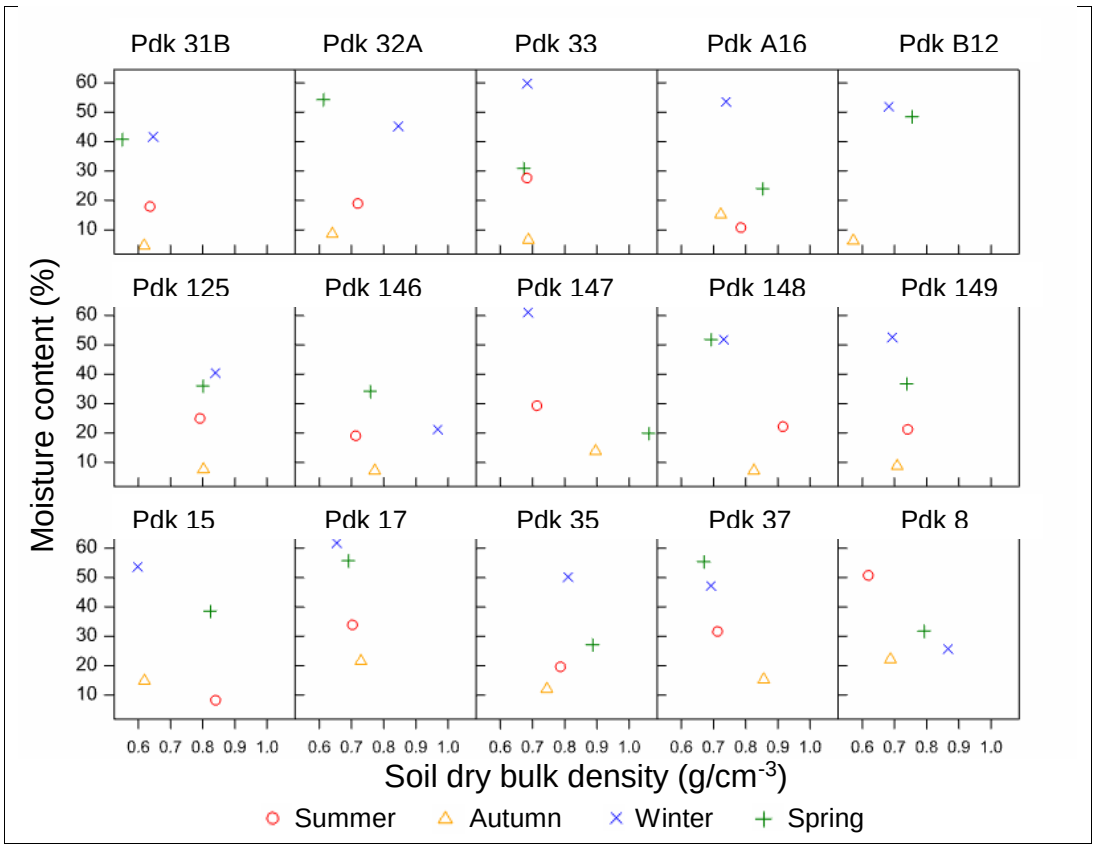
Moisture content and soil dry bulk density – 10-20 cm depth



Moisture content and penetration resistance – 20-30 cm depth

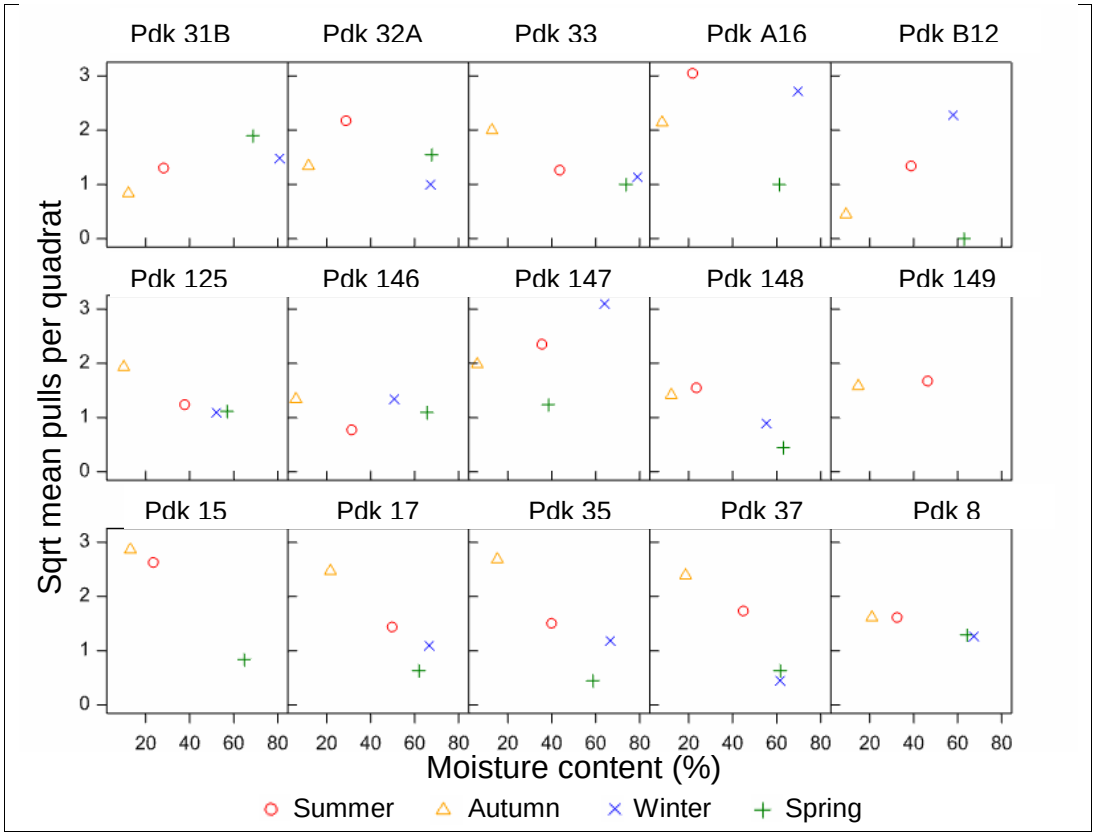


Moisture content and soil dry bulk density – 20-30 cm depth

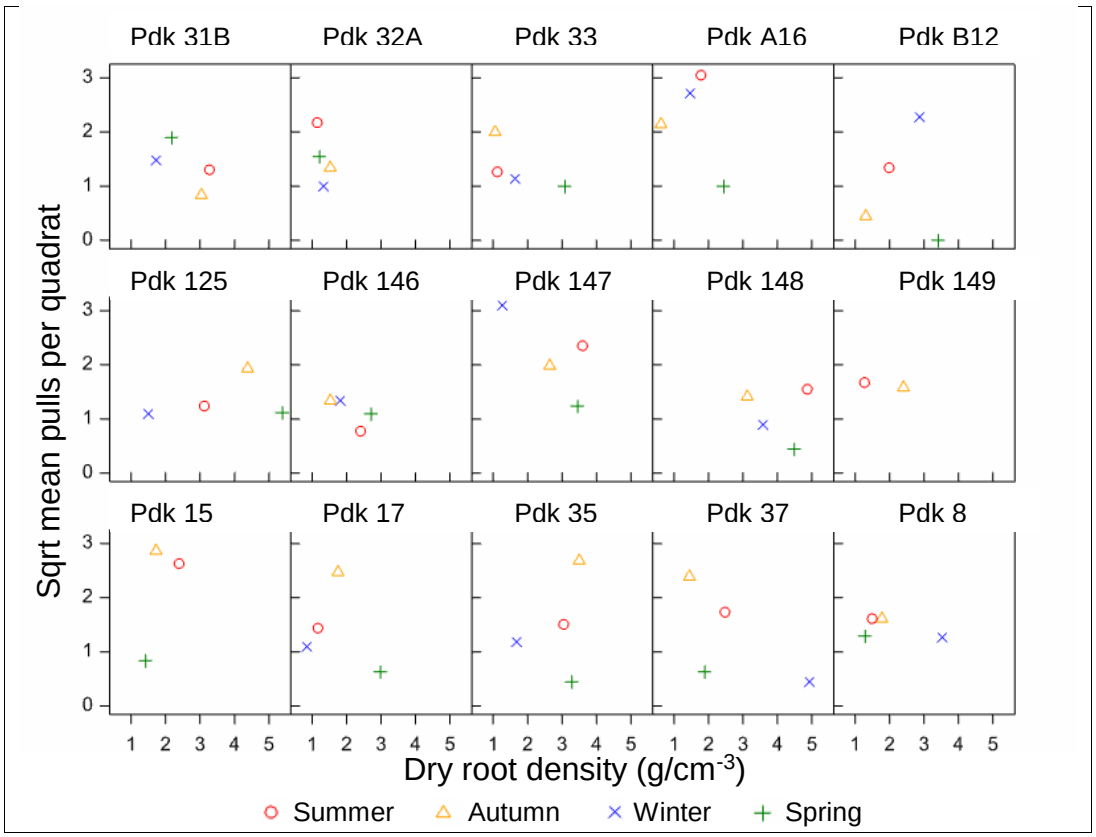


Trellis plots for significant relationships between pasture pulling and soil parameters

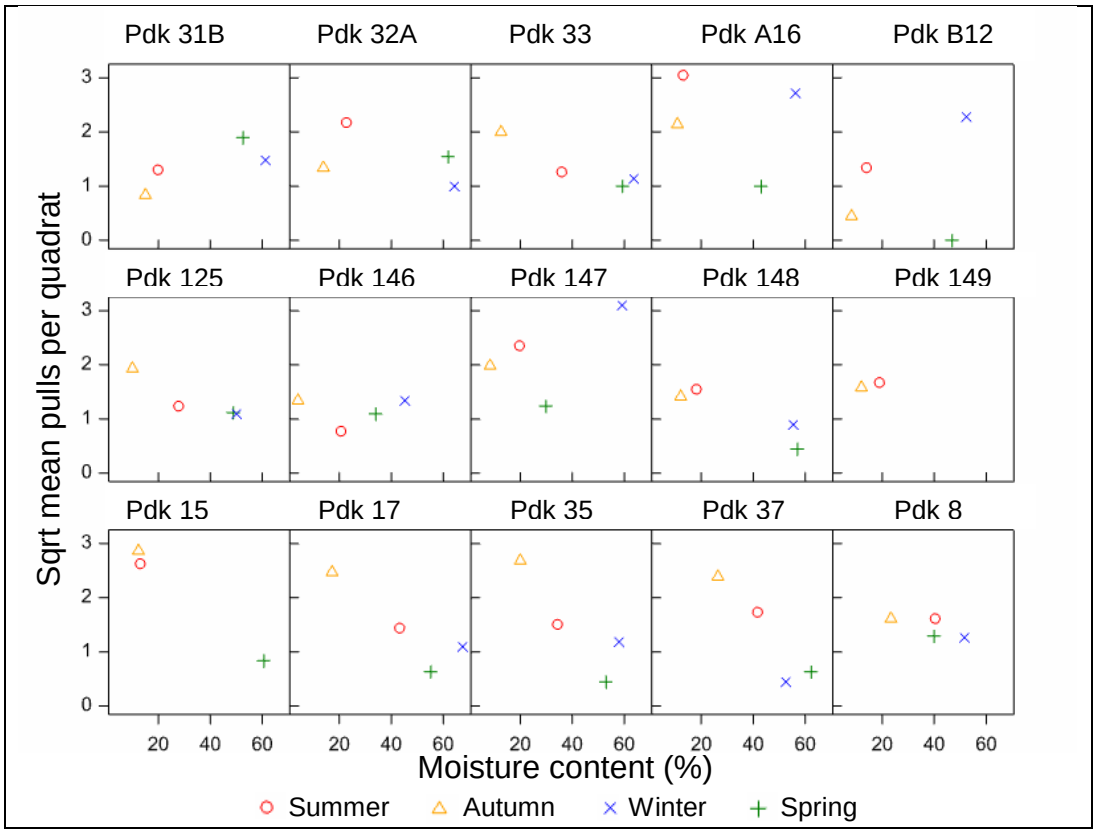
Pasture pulling and moisture content – 0-5 cm depth



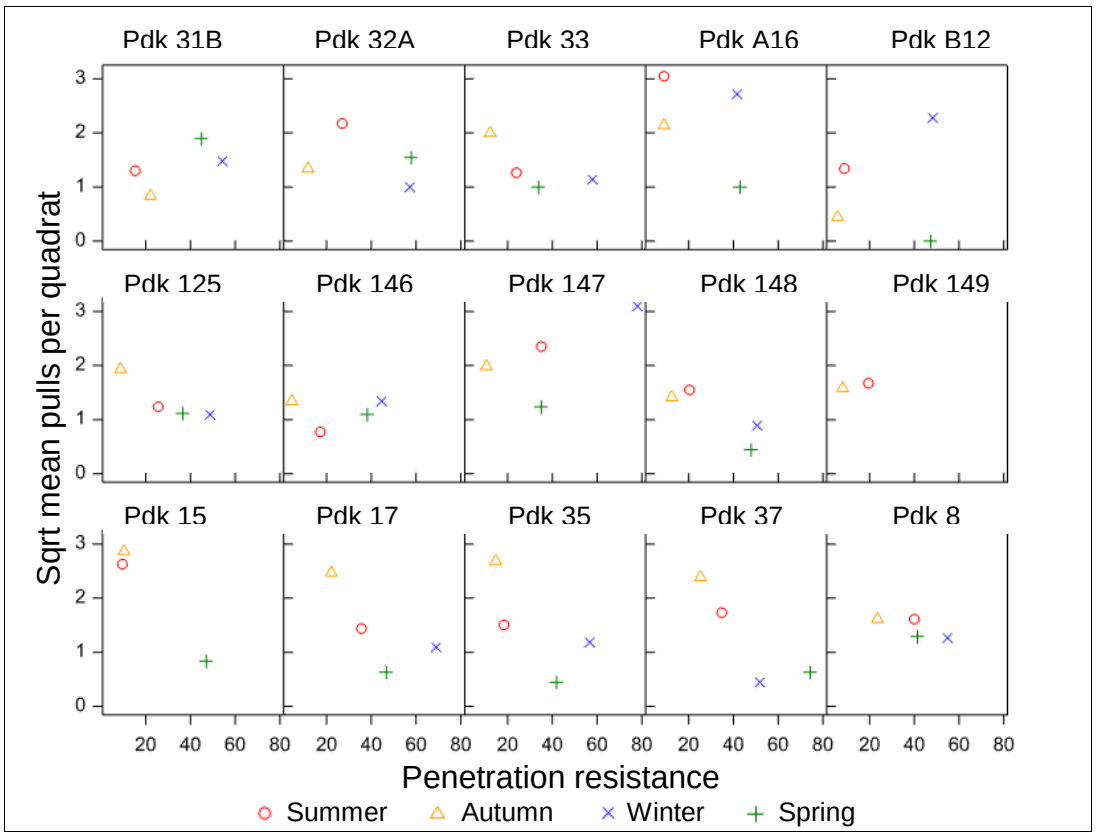
Pasture pulling and dry root density – 0-5 cm depth



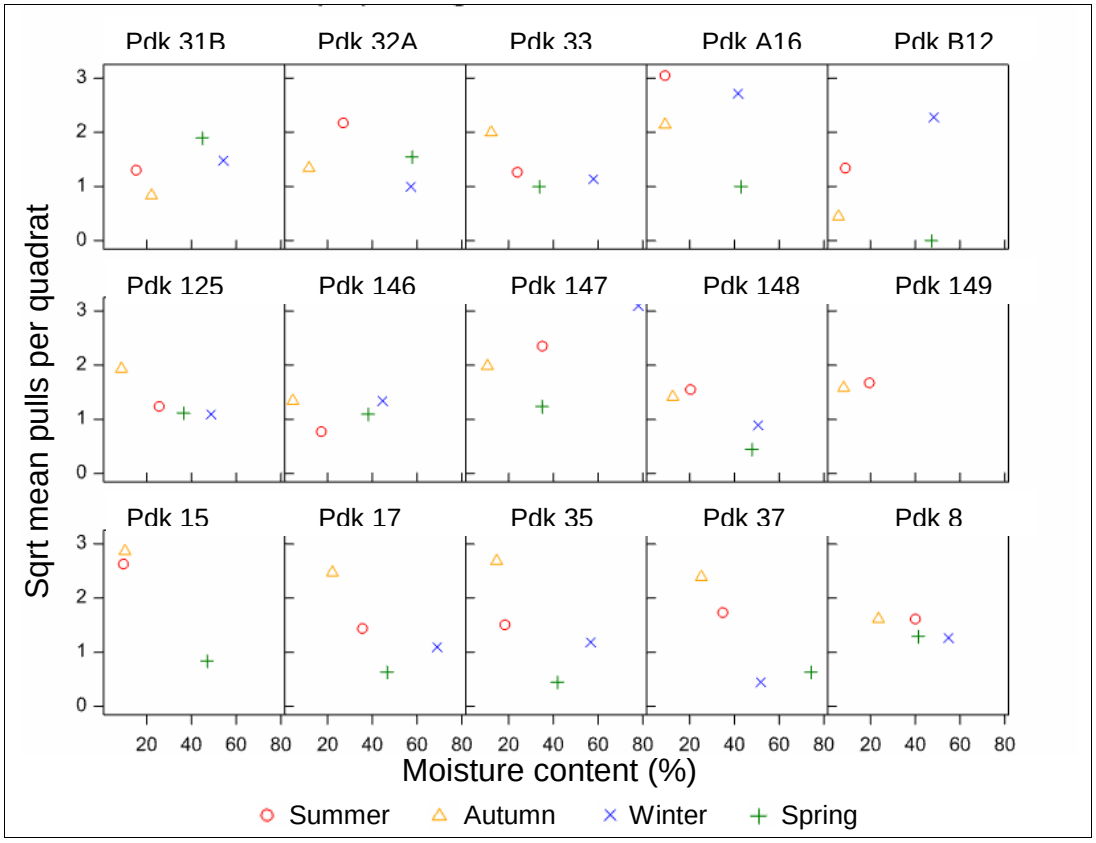
Pasture pulling and moisture content – 5-10 cm depth



Pasture pulling and penetration resistance - 10-20 cm depth



Pasture pulling and moisture content – 10-20 cm depth



Pasture pulling and penetration resistance – 20-30 cm depth