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Effects of Live and Dead Plant Matter on the Stability of pH, Redox Potential and Sulphate Content of Sulphuric Soil Material Neutralised by Addition of Alkaline Sandy Loam

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ABSTRACT

Sulphuric soil material of acid sulfate soils is mainly managed by the addition of mineral lime but lime availability is limited to a few regions and pure mineral lime is expensive. This study assessed the stability of sulphuric soil material neutralised by the addition of alkaline sandy loam, with organic matter amendment or establishment of plants. Incorporation of organic matter stabilised the pH but did not prevent oxidation under aerobic conditions. Under flooded conditions, the pH was more stable and increased when organic matter was incorporated. Application of organic matter to the surface was only effective under flooded conditions. In contrast to the effects of plants on sulphidic soil material and sulphuric soil material where the tendency was to increase growth of plants on neutralised sulphuric soil material had little influence on pH. In addition, the changes induced by smaller plants were comparatively lower, and dependent on the organic matter turnover from above and below ground biomass.

Keywords: **Sulphuric soil material, alkaline sandy loam, neutralised soil, organic matter, live plants, pH, Eh**

INTRODUCTION

Acid sulphate soils (ASS) are naturally occurring soils, sediments or substrates formed under waterlogged (reduced) conditions (Fitzpatrick *et al*. 2008; Fanning 2012; Michael 2013). Pons (1973) described ASS as the "nastiest soils" on earth because of a series of serious ecological and environmental impacts (Baldwin and Fraser 2009; Buschmann *et al.* 2008). Some of these negative impacts have been reviewed and documented by Michael (2013). The negative impacts are of global significance because ASS distribution is estimated to be 17-24 million ha (Poch *et al*. 2009) of which 6.5 million ha occur in Asia, 4.5 million ha in Africa, 3 million ha in Australia, 3 million ha in Latin America, 200 000 ha in Finland and 100 000 ha in North America, respectively (Simpson and Pedini 1985). ASS containing sulphuric acid has been classified as sulphuric material (pH<4) and those containing iron sulphide (pyrite, FeS_2) as sulphidic material (pH >4), respectively (Isbell 2002).

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Under inundated (reduced) conditions, the negative impacts of ASS are considered minimal but if these soils are exposed (disturbed), the sulphides are oxidised and sulphuric acid is produced and released (Simpson *et al*. 2010). The principle option to manage sulphuric material is to neutralise the "sulphuric acidity" with a neutralising agent (Fitzpatrick *et al*. 2010), e.g. agricultural lime. The principle management option of sulphidic material is to minimise disturbance and prevent exposure to atmospheric oxygen. Sulphuric acidity is neutralised by application of agricultural lime but its availability is limited to a few areas and is relatively expensive in other regions (Shamshuddin *et al.* 2004). Oxidation of sulphidic material by exposure is mainly prevented by submergence through flooding but under conventional soil use and management conditions, land users and managers consider flooding as not desirable (Hanhart *et al*. 1997). In addition, the ever increasing need for food and socio-economic development is exerting continuous pressure on wetlands containing sulphidic material to be converted into agricultural farms and as space for infrastructure development consequently expos sulphidic material. The negative impacts of ASS and the convention of leaving material untouched under inundation to prevent oxidation provides for a vulnerable situation. Research is certainly needed to develop effective and user-friendly management strategies.

Various studies have established that incorporation of organic matter neutralises sulphuric soil material acidity (i.e. increases the pH) and prevents sulphidic soil oxidation (i.e. stabilises the pH) when exposed and is an alternative management option for ASS (Michael *et al.* 2015; Michael 2015; Michael *et al*. 2016). Similar results were reported by Jayalath *et al.* (2016) and Reid and Butcher (2011). The advantages of using organic matter are that it is relatively cheap and readily available compared to mineral lime. We have shown too that the presence of plants on either sulphuric soil or sulphidic soil material increases acidification when vegetated even if the turnover of plant materials offsets the negative impacts (Michael *et al.* 2017).

In many ASS, a heavy texture does not allow penetration of neutralising agents, such as lime, and are not conducive to plant growth. Improvement to poor texture can be achieved by various methods to allow better penetration of water to facilitate leaching of excess salts, and better penetration of oxygen for plant growth. In a short incubation study lasting 2 weeks, we have shown that addition of alkaline sandy loam neutralises sulphuric soil material acidity and prevents oxidation of sulphidic soil material o (Michael *et al.* 2012). This short-term study was extended to assess long-term (6 months) stability when alkaline sandy loam was added to sulphuric soil material and the pH raised to near neutral of 6.7. The results obtained indicated that the neutrality obtained after mixing the sulphuric soil material with alkaline sandy loam was stable over a period of 6 months (Michael, 2014). The stability of the neutralised sulphuric soil material, under normal soil use and management conditions, such as in revegetation of an acid scalded environment, however was not clearly established. Therefore, this study was conducted to assess the effects of live and dead plant matter on the stability

of pH and the redox potential of sulphuric soil material of ASS neutralised by addition of alkaline sandy soil.

MATERIALS AND METHODS

Acid Sulfate Soils

Sulphuric soil material (Soil Survey Staff 2014) was collected from the surface soil (within a profile of 0.5-1.5 m) in Gillman (34°82′92.3″S, 138°54′05.0″E), Finnis River, South Australia. The pH of the freshly collected sulphuric soil material measured in water (pH_w) 1:5 (soil: water) was 2 and the pH following peroxide treatment (pH_{ox}) (Sullivan *et al*. 2009; Sullivan *et al*. 1999) was 0.9, with the water holding capacity estimated to be 79%. pH_w, pH_{ox} and water holding capacity of the sulphidic soil material collected from the same site at a depth of 1.6-3.5 m ranged from 5.6-6.7, 1.9-2.3, and 48%, respectively. The residual organic matter content, estimated using the weight loss-on-ignition method (Schulte and Hopkins 1996).

Alkaline Sandy Loam and Neutralisation of Sulphuric Soil Material

In order to neutralise the sulphuric soil material by mixing, bags of alkaline sandy loam (hereafter ASL) were purchased from a local supplier in Adelaide, South Australia. The pH_w was 9.4 and pH_{ox} was 7.2, respectively. To neutralise the sulphuric soil material, ASL was initially added at a ratio of 3:1 (ASL: Sulphuric soil material, w/w) and mixed using a cement mixer. The process was repeated until an adequate amount of the neutralised soil was obtained. The final pH_w, pH_{ox} water holding capacity and sulfate content of the neutralised soil prior to use was 6.7, 2.8, 28% and 23 μmol g^{-1} soil, respectively. The "neutralised sulphuric soil material" is hereafter referred to as "neutralised soil".

Organic Matter

Dried leaves of *Phragmites australis* (3.7% nitrogen analysed using LECO), collected from the second visible dewlap (the last 3 leaves of first 6 leaves) were ground using an electric blender to pass through a 0.5 mm sieve and used as organic matter (Michael *et al.* 2015). Drying was done by leaving the leaves in an oven at 60^0C for 3 days until the leaves were sufficiently brittle to be ground by placing them in the blender.

Plants

To investigate the stability of the neutralised soil in the presence of small plants, wheat and lucerne were established by direct sowing of seeds obtained from crops grown for this study. To investigate the effects of big plants, *Allocasurina*, *Eucalyptus calycogona* and *Melaleuca amillaris* were established by transplanting 6-8 weeks old seedlings. These seedlings were raised in a medium (compost: sand loan 2:1) from seeds purchased from a local supplier in Adelaide, South Australia.

Experimental Treatments

Experiment 1

Under general soil use and management conditions, dead plant matter is added either on the surface (e.g. leaf litter) or incorporated into the soil as organic matter (e.g. in the form of death roots). Naturally, addition of organic matter conserves soil moisture and controls weeds, whereas incorporation of organic matter supplements the soil with nutrients and improves soil texture by the addition of fibre. The scenarios of dead plant matter being added either on the soil surface or incorporated throughout the soil profile were investigated in experiment 1.

Using small pots, two sets of experiments were set. In both sets, 1 g of ground *Phragmites australis* (common reed) leaf as "organic matter" was either "overlaid" on the surface or "incorporated" by weighing using 90g of the neutralised soil or sulphidic soil material. Where organic matter was incorporated, careful mixing was done using a soil scoop to ensure homogeneity. In the first set, organic matter was overlaid on the surface and kept under either aerobic or anaerobic condition. In the second set, organic matter was overlaid on the surface but maintained under flooded ("anaerobic")soil condition only. This study was set using naturally occurring sulphidic soil material collected from Gilman. Mixing of this soil with ASL was done as described above.

Experiment 2

This experiment was set using 50 cm long stormwater tubes (pipes) with one end tightly capped and sealed with waterproof sealants. The bottom 22 cm capped end of each tube was filled with acid washed, carbonate free sand and the top 22 cm filled with 1300 kg of the neutralised soil. As in the first experiment, weighing was done to ensure equal amounts of sand and neutralised soil were added.

In the neutralised soil, wheat as crop, lucerne as forage and *Allocasurina, Melaleuca* and *Eucalyptus* as trees were established. The crop and forage plants were sown directly as seeds and the trees established by transplanting 6-8 weeks old seedlings. Throughout the study, all the plants that grew reached maturity. In all the experiments, control treatments were set up in a similar manner as the treatments except that no organic matter was either overlaid or incorporated in Experiment 1, and no plant was established in Experiment 2. The treatments were replicated four times and set up in a randomised complete design (RCD) under glasshouse conditions. Only three of the replicates were used for data collection.

Watering and Management

Watering was done as per Michael *et al*. (2017). All the treatments under aerobic condition received water on three days (Monday, Wednesday and Saturday). The treatments under anaerobic conditions were watered twice daily to ensure that organic matter and the neutralised soil were covered in water, with a sufficient amount of water ponding on the surface to maintain anaerobic soil condition. All the organic matter and soil moisture experiments were maintained for 6 months to ensure complete decomposition of the dead plant matter (Michael *et al.* 2015).

As would be in a farm, the crop and forage plants were fertilised with pre-prepared 100ml of a complete Hoagland solution on a monthly basis until harvest. An additional treatment with a similar number of replicates without plants was included and fertilised to assess whether fertilising had an effect on the measurements made. The crop and forage plants as well as the trees were harvested (measurements) after 12 months of growth. As would be under natural conditions, senesced leaves that had fallen were not removed. The fallen leaves on the surface and dead roots throughout the profiles, upon decomposition, would induce change in the soil chemical characteristics measured.

Biomass

Root biomass was quantified as described by Michael *et al*. (2017). To quantify the root biomass followed by soil sampling for pH measurement, the storm water tubes were marked out at 0-20, 20-50, 50-100, 100-150, 150-200 and 200-300 mm (the profiles from which the changes in soil redox potential (Eh) in the presence of plants were measured) and cut into small sections using a handheld electric saw. Soil from these sections were placed in a sieve (0.05 mm) and held under gentle running tap water and the soil carefully broken up to free the roots using the aid of forceps.

The loose soil particles were allowed to drain through but roots that were trapped by the sieve and started floating during washing were collected. These roots were taken, gently washed again to remove soil material, placed in weighing boats and oven dried for 48 h. Dry weight was taken by weighing and the weights of the replicates were pooled, averaged and served as final data. Only data from the surface (20 mm), middle (100 and 200 mm) and deep (300 mm) are presented.

Measurements

Redox was measured using a single Ag/AgCl reference and platinum (Pt) electrode combination using an automated data logger (Dowley *et al.*1998). To measure the Eh, the frame of the redox probe was marked as per the targeted profile from the tip (e.g. 0-10 mm etc. to 300 mm). To do this, the storm water tubes used in Experiment 2 were marked out as per the intended depths, and an electric drill with a bit head similar to the size of the Pt tip was used to make holes. The holes were sealed immediately with packing tape to prevent oxygen entry prior to the Eh measurement.

During Eh measurement, the reference electrode was inserted into the surface and Pt electrode either in the surface (Experiment 1) or from the side using the holes created as described above (Experiment 2). In all the experiments, the reference electrode remained inserted while the Pt electrode was driven invariably one at a time into the soil from the surface (Experiment 1) or from the side (Experiment 2). Depending on the profile depth, the Eh was intended to be logged (Michael *et al.* 2015; 2016). This was allowed to equilibrate for 10 min and then Eh logged at 1 min intervals for the next 10 min and averaged (Rabenhorst *et al*. 2009). These values were corrected for the reference offset to

be relative to the potential of a standard hydrogen electrode by adding 200 mV (Fiedler *et al.* 2007). The stability and accuracy of the electrodes were maintained as per Fiedler *et al*. (2007).

To obtain soil samples for pH measurement of Experiment 1, a core sampler (25 mm in diameter) was driven into the soil, and a core carefully taken out. The soil cores were placed along a 30 cm ruler and cut into pieces using the graduation on the ruler as a guide, with a piece of core containing soil from which Eh was measured. For the studies described under Experiment 2, a cut section containing the soil from which Eh was measured was used. pH was measured using 2 g soil (1:5 water) sample (replicate) either from the cut cores or stormwater tube sections with a pre-calibrated Orion pH meter (720SA model) (Michael *et al.* 2015).

In addition to the effects on pH and Eh, dead plant matter in the form of dead leaves (that fall on the soil surface) and root (in different profiles of the soil) have an effect on soil sulphate content (Michael 2015). This scenario was tested by qualifying the sulphate content using soil samples of Experiment 1 where organic matter was added. The sulphate content of the neutralised soil in Experiment 2 was not done as the data from Experiment 1 with organic matter overlaid on the surface or incorporated in the soil would serve the same purpose, under varying soil moisture conditions.

Sulphate was extracted according to the method of Hoeft *et al*. (1973) for soluble soil sulphate. Replicate samples (0.5 g each) from the cut soil core of Experiment 1 or soil inside the cut stormwater tubes of Experiment 2 were placed in tubes with 1.5 mls of an extraction solution (0.2 g CaH_2PO_4, 12 g glacial acidic acid, and 88.5 g deionised water). After 30 min, the soil was sedimented by centrifugation for 5 min and duplicate aliquots from the three replicates were transferred into 4 ml cuvettes and diluted with 1.5 ml of the extraction solution. The samples were mixed with 0.7 ml of 0.5 M HCl and then 0.7 ml of 0.1 M barium chloride-polyethylene glycol reagent was added and mixed again. After 10 min, the samples were mixed again and the absorbance read at 600 nm using a spectrophotometer. The readings were compared to a standard solution of 0-2 mM Na_2SO_4. The initial sulphate content of the sulphuric and sulphidic soils ranged from 21-32 to 12-16 µmol g^{-1} soil.. The detection limit based on an absorbance reading of 0.1 of the Hoeft *et al*. (1973) method was 0.6 µmol g^{-1} soil.

In Experiment 1, measurements made from the 0-10, 10-20, 20-40 and 40-80 mm profiles are presented. For the first set of experiment with organic matter overlaid and maintained under aerobic conditions, only the surface (10 mm), middle (40 mm) and deep (80 mm) profiles data are presented. For the same experiment with both the organic matter and neutralised soil maintained under anaerobic conditions, data from the surface (10 mm) and deep (80 mm) profiles only are presented. The reason for only surface and deep data being used was because the surface soil was under frequent fluctuating water level whereas the deep soil was consistently submerged in water, as would be under flooded (reduced) soil conditions. In the second set of experiments where organic matter

was incorporated and maintained under aerobic conditions, data from the surface (10 mm), middle (40 mm) and deep (80 mm) are presented. The component of this experiment maintained under flooded soil conditions, data on the surface (10 mm) and deep (80 mm) profiles are presented..

In Experiment 2 (set up in 45 cm stormwater tubes), measurements were made from the 0-20, 20-50, 50-100, 100-150, 150-200 and 250-300 mm profiles. For both sets of experiments (crop and forage plants receiving nutrient)and tree plants, data collect from the surface (20 mm), middle (100 - 200 mm) and deep (300 mm) are presented.

In all the experiments, the profiles from which the data were collected from the two experiments were dictated by the size of the small pots and the stormwater tubes used.

Statistical Analysis

Statistical analysis was done as reported in various studies (Michael *et al.* 2015; 2016; 2017). The Eh values obtained over a 10-min period were averaged and a treatment average obtained by taking the mean of the three replicates. Similarly, treatment average pH was obtained by taking the mean of the three replicates. To compare the treatment means, significant differences ($p<0.05$) between treatment means of each profile was determined by two-way ANOVA using statistical software JMPIN, AS Institute Inc., SAS Campus Drive, Cary, NC, USA 27513. If an interaction between the treatments and profile depths was found, one-way ANOVA with all combinations was performed using Tukey's HSD (honest significant difference) and pairwise comparisons.

RESULTS AND DISCUSSION

Effects of Organic Matter on Neutralised Soil Eh, pH and Sulphate Content

The changes in neutralised soil pH, redox and sulfate content measured following incorporation of organic matter and maintained under aerobic conditions are shown in Figure 1. During the months of incubation, pH of the unamended control soil was stable at the surface but decreased sharply to 4.5 at depth (Figure. 1a). Incorporation of organic matter sustained the pH between 5 and 6 across the profiles, but became more acidic than the initial pH by 1 unit.

The redox changes were hard to interpret (Figure 1b). In all cases, the soils remained moderately to highly oxidised with similar values recorded for the control soil at pH 6.6 (surface) and pH 4.4 (80 mm depth) (Figure 1b). The sulphate content was fairly consistent across the profile in the control soil (Figure 1c). In the organic matter amended treatment, sulphate content decreased sharply from the surface to the deep profiles.

Figure 2 shows the changes in the neutralised soil pH, redox and sulphate content measured following incorporation of organic matter and maintained under flooded conditions. Compared to the initial pH, the unamended control soil acidified to near 5 at the surface but increased slightly to 7 at depth (Figure 2a).

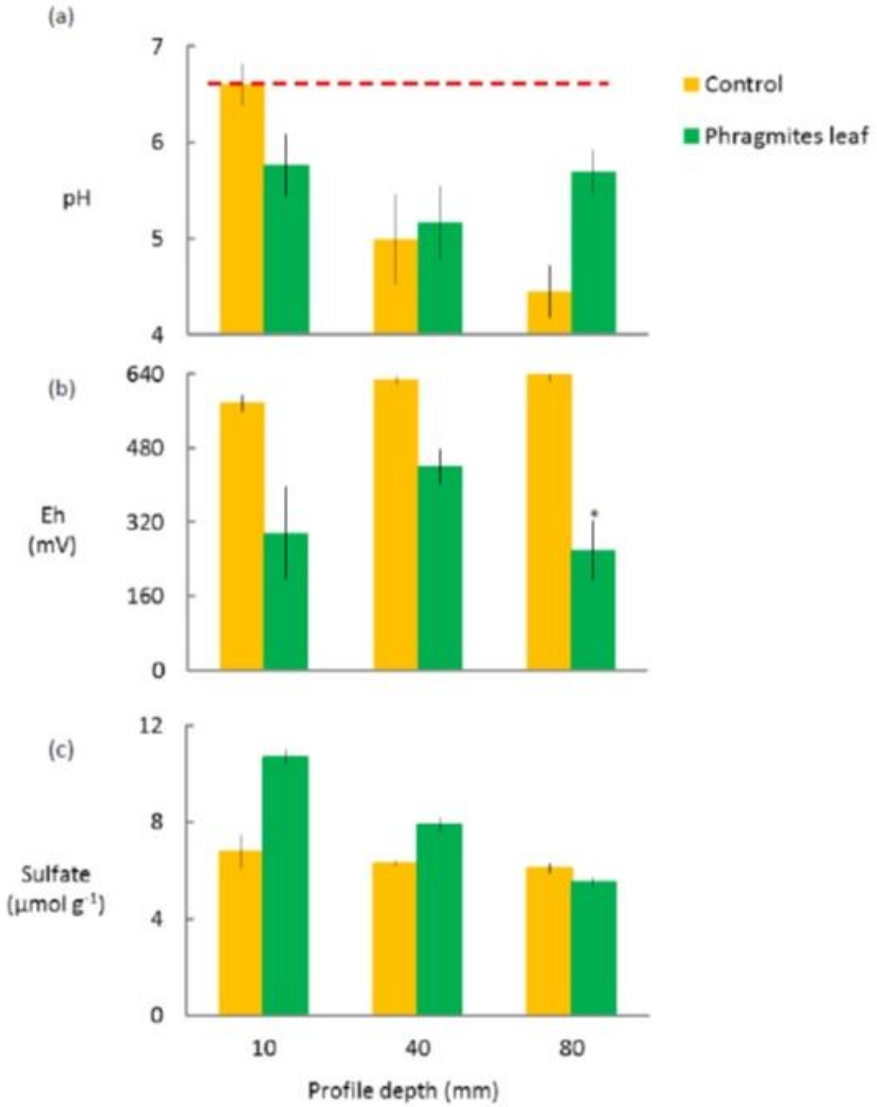

Figure 1: Effects of incorporated organic matter on (a) pH, (b) redox and (c) sulphate content of neutralised soil maintained under aerobic conditions for 6 months. The red dotted line is the initial pH. The initial sulphate content of the neutralised soil is 23 µmol g^{-1} soil. The values are means ± s.e. of three measurements (n=3). Asterisks indicate significant differences ($p<0.05$) between treatments and control at the same depth.

Organic matter caused the pH to increase by 0.6 – 1 unit across the profile. The pH changes broadly corresponded to the reciprocal changes in Eh (Figure 2b) and sulphate content (Figure 2c).

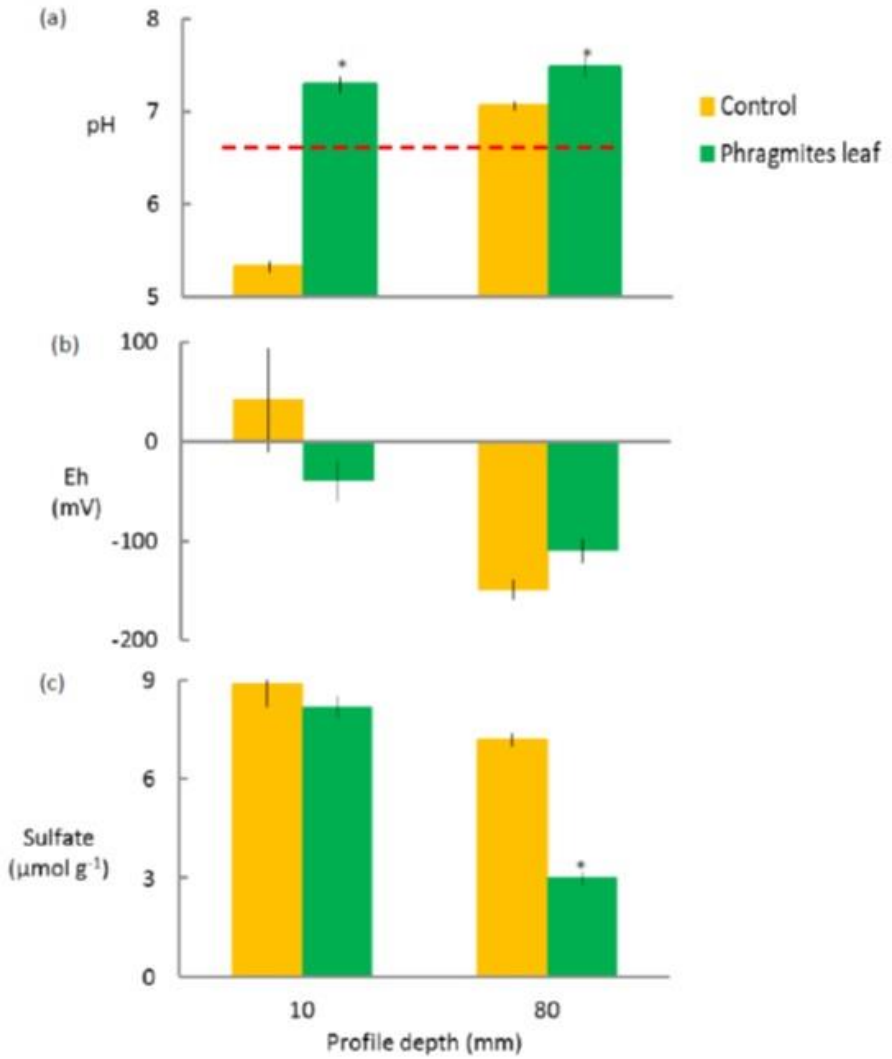

Figure 2: Effects of incorporated organic matter on (a) pH, (b) redox and (c) sulphate content of neutralised soil maintained under anaerobic conditions for 6 months. The red dotted line is the initial pH. The initial sulphate content of the neutralised soil is 23 µmol g-1soil. Values are means ± s.e. of three measurements (n=3). Asterisks indicate significant differences ($p<0.05$) between treatments and control at the same depth.

When organic matter was overlaid and maintained under aerobic conditions, the pH of the control treatment remained stable around 6.8 at the surface, but decreased strongly to around 4.3 at depth (Figure 3a). Addition of organic matter to the surface caused moderate acidification, which increased slightly with depth.

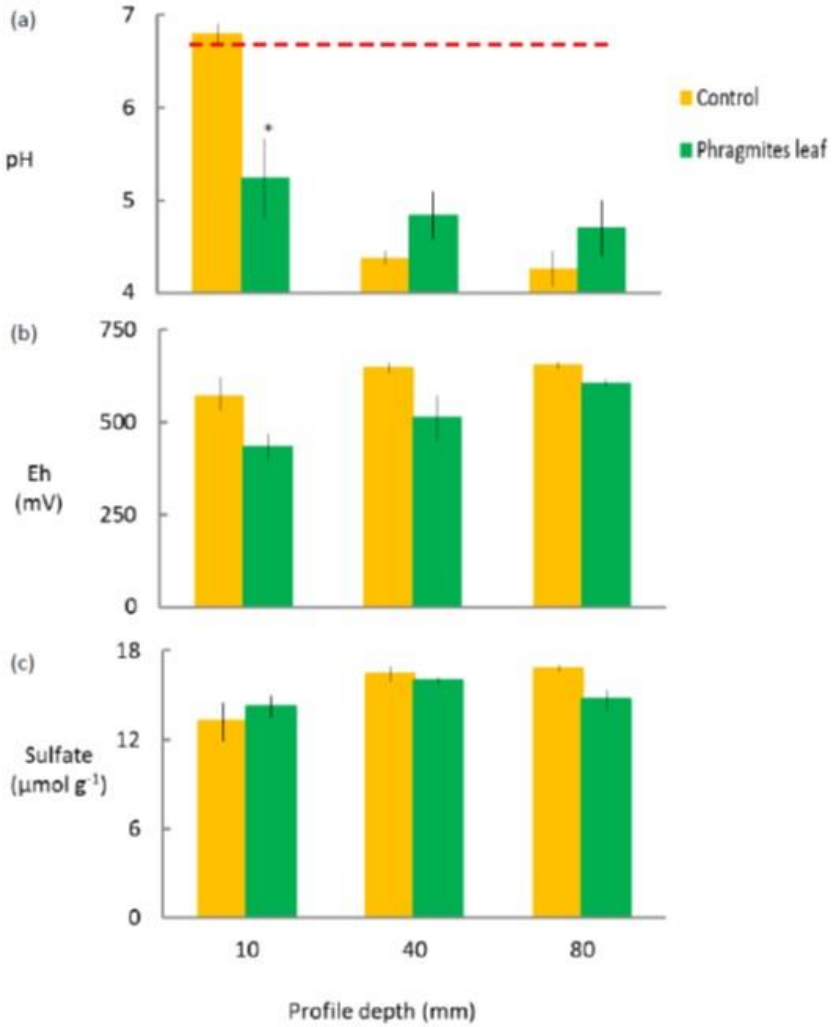

Figure 3: Effects of overlaid organic matter on (a) pH, (b) redox and (c) sulphate content of neutralised soil maintained under aerobic conditions for 6 months. The red dotted line is the initial pH. The initial sulphate content of the neutralised soil is 23 µmol g^{-1} soil. The values are means ± s.e. of three measurements (n=3). Asterisks indicate significant differences ($p<0.05$) between treatments and control at the same depth.

Despite the changes in pH, the Eh (Figure 3b) and sulphate content (Figure 3c) of all treatments varied very little. However, the sulphate content after 6 months was much lower than the measured initial content, indicating the disappearance (most likely by reduction) of a significant amount of sulphate.

Under flooded conditions, the pH of the control sulphidic soil decreased slightly to near 6 at the surface and to 5.3 at depth, whereas in the organic matter treatment, the pH rose sharply at the surface to more than 8 but was similar to the

control soil at depth (around 5.7) (Figure 4a). Despite the flooded soil condition, the presence of sandy loam soil facilitated movement of oxygen into the soil, allowing the control soil to remain fairly oxidised, compared to the organic matter treatment which was quite reduced (Figure 4b). There was only a very weak correlation between pH changes (Figure 4a) and the sulphate content (Figure 4c); the soils with higher pH values tended to have a low sulphate content.

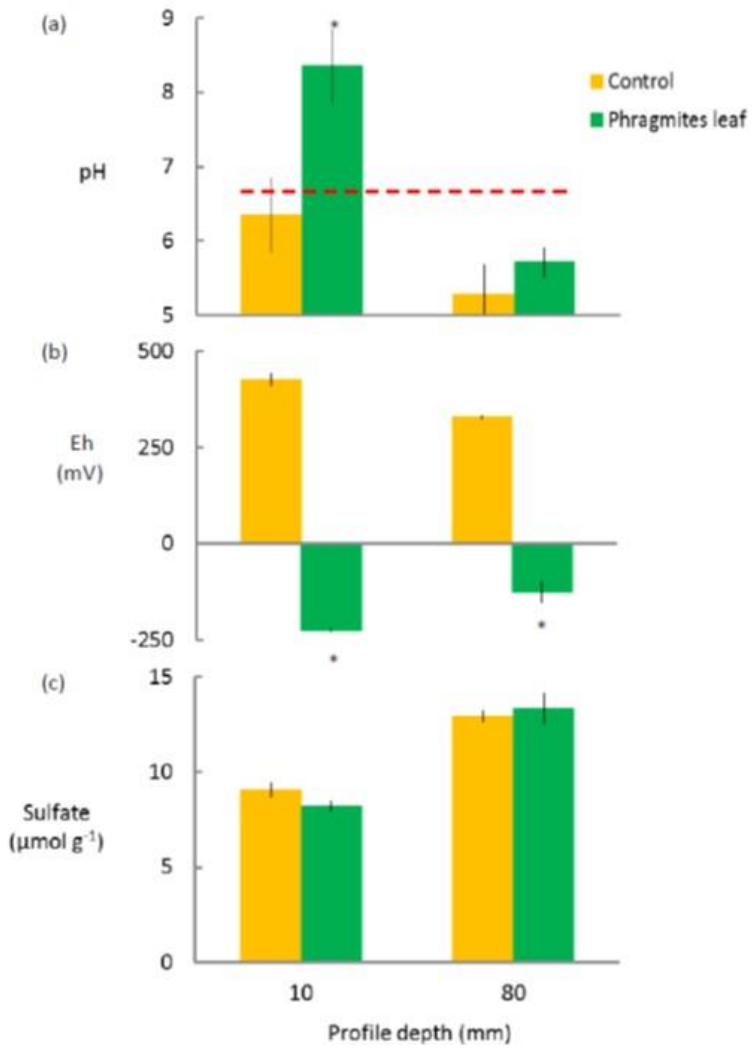

Figure 4: Effects of overlaid organic matter on (a) pH, (b) redox and (c) sulhate content of sulphidic soil maintained under anaerobic conditions for 6 months. The red dotted line is the initial pH. The initial sulphate content of the unamended sulpidic soil is 16 µmol g^{-1}soil. Values are means ± s.e. of three measurements (n=3). Asterisks indicate significant differences ($p<0.05$) between treatments and control at the same depth.

The data presented in Figure 2b show that under similar anaerobic conditions, incorporation of organic matter highly reduced the Eh of the neutralised soil and kept that of the control treatment fairly reduced (Figure 2b). These contradicting results may mean that addition of ASL into naturally occurring sulphidic soil material is not the best option but is a better option to manage sulphuric soil material. These results could mean too that overlaying of organic matter is not an ideal strategy compared to the effectiveness of incorporation of organic matter to have an effect on soil properties (Michael *et al.* 2015).

Impacts of Vegetation on Neutralised Sulfuric Soil pH and Redox

Mixing of ASL with sulphuric soil material has the combined advantages of raising the pH into the range where most plants grow optimally, and creating a more open texture for root growth. This is an important approach to manage areas like an acid scalded farm to establish plants. In this study, a range of plants was grown with or without supplemental fertiliser in the neutralised soil to examine their impact.

The root biomass obtained from the profiles 20 (0-20 mm), 100 (50-100 mm), 200 (150-200 mm) and 300 mm (250-300 mm) of the smaller and larger plants are respectively shown in Figure 5a. Fertilising had a small to no effect on the neutralised soil pH and Eh remained within the oxidised ranged as in the other treatments (data not shown). Fertilisation however greatly increased the growth of both lucerne and wheat as expected but the root biomass of the lucerne within the surface was comparably higher (2 g), compared to the wheat treatment (Figure 5a). This is not surprising as root biomass of legumes accumulates greatly near the surface, particularly when fertilised, e.g. under crop plantations. Compared to the control, lucerne acidified the neutralised soil pH, consistent with the results of Yan *et al.* (1996).

Near the surface, the pH remained relatively stable for all treatments except for the fertilised treatment with wheat plants (near 8 units), compared to the other treatments which remained unchanged (Figure 5b). Lower in the profile, the control soil acidified to around pH 5, with similar values recorded for most of the treatments. There was no clear pattern of change connecting pH to Eh, the only noticeable feature being that the Eh of the unfertilised wheat treatment tended to be lower than the other treatments (Figure 5c). The apparent lack of effect of the planted treatments may be due to the relatively small amount of biomass turnover contributed by the roots. Presence of sandy loam, plant roots and the aerobic condition facilitated oxygen entry, allowing the neutralised soil Eh to remain highly oxidised (Eh ranging from 450-600 mV) (Figure 5c). Under highly oxidised soil conditions, soil pH is expected to be lower ($pH \leq 4$). This was observed, at least in the lower profiles (Figure 5b), a clear indication that changes in soil properties measured were induced by natural processes, as would be, in any soil type.

Figure 6 shows the effects of the larger plants, *Allocasuarina, Eucalyptus* and *Melaleuca*. The results were highly variable and no clear trend was discerned,

also no predictable relationship between root biomass, pH and Eh was found. Except in the 100 mm profile of the *Melaleuca* treatment, root biomass was equally produced by all the plants throughout the profiles (Figure 6a). However, in all cases, the final pH of all the treatments was higher than the initial pH (Figure 6a), which is more likely due to the stabilising effect of alkaline components of the sandy loam as well as to the fact that the neutralised soil may contain fewer oxidisable sulphides.

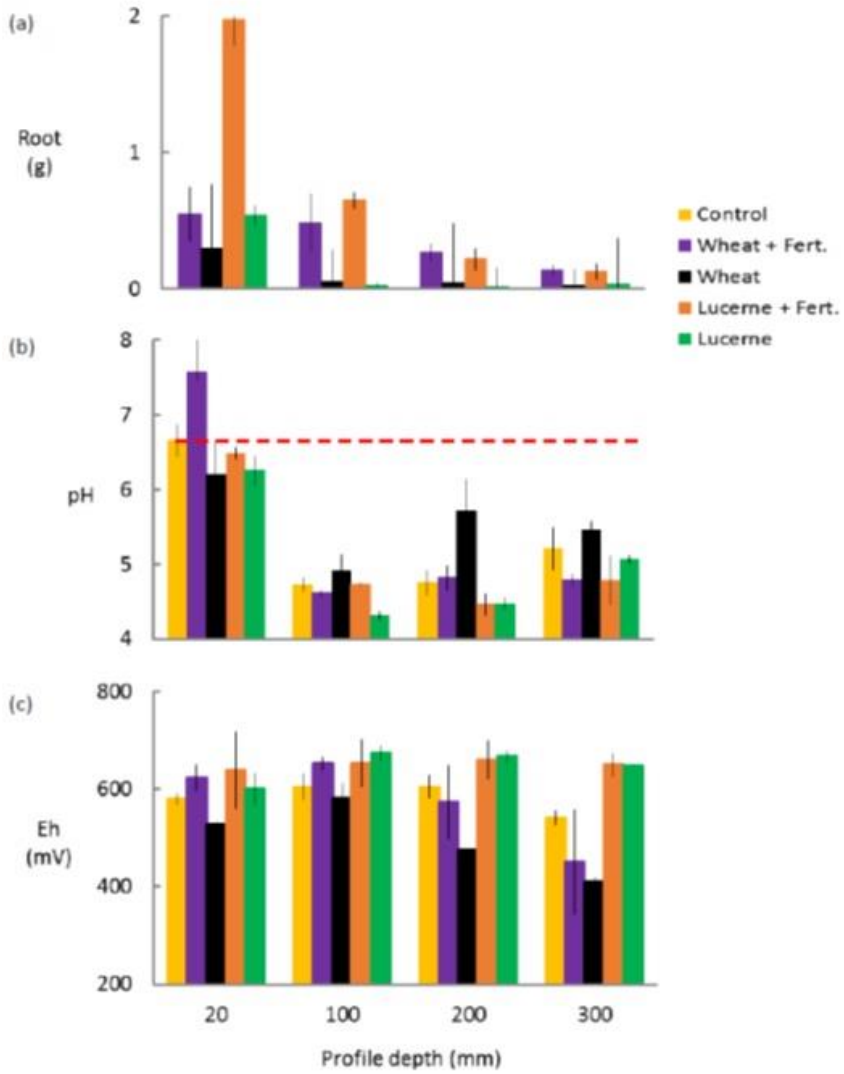

Figure 5: Effects of (a) roots of wheat and lucerne plants on (b) pH and (c) redox of neutralised sulphuric soil maintained under aerobic conditions for 12 months. The red dotted line is the initial pH. Values are means ± s.e. of three measurements (n=3). No significant differences ($p<0.05$) between treatments and control soil properties were observed at the same depth.

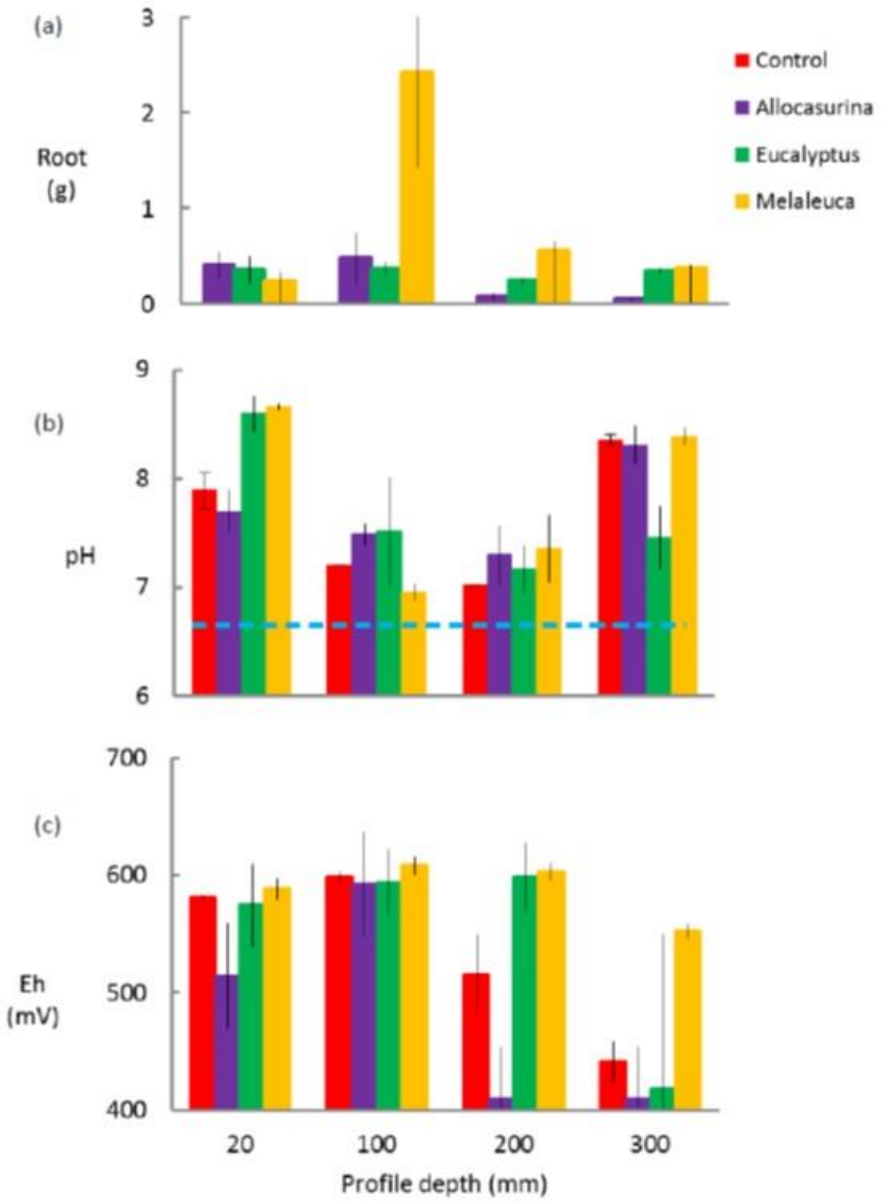

Figure 6: Effects of (a) roots of trees on (b) pH and (c) redox of neutralised sulphuric soil maintained under aerobic conditions for 12 months. The values are means ± s.e. of three measurements (n=3).The blue dotted line is the initial pH. No significant differences ($p<0.05$) between treatments and control soil properties were observed at the same depth.

The data presented in Figures 5 and 6 show no clear relationship between the plant types and the changes in soil chemistry, measured on the neutralised soil. The changes in pH and Eh in the planted treatments were similar to those

of the control, a strong indication that the chemistry of the neutralised soil was stable, regardless of whether small plants or bigger ones were established. The data showed too that in addition to the changes induced by the alkaline nature of the sandy loam, the noticeable changes in soil properties, especially in the surface profiles, were plant dependent. A smaller amount of organic matter turnover occurred in the planted treatments, compared to the bigger plants. This is the reason the changes in surface soil pH measured in the presence of small plants was small (Figure 5b) compared to the surface soil pH of the treatments with bigger plants (Figure 6b).

CONCLUSION

Neutralised soil is expected to contain fewer sulphides compared to the equivalent naturally occurring sulphidic soil material before oxidation. Nevertheless, these soils still acidified at depth, but less than the sulphidic soil material. Incorporation of organic matter stabilised the pH but did not prevent oxidation under aerobic conditions. Under flooded conditions, the pH was more stable and increased when organic matter was incorporated. Application of organic matter to the surface was only effective under flooded conditions. In contrast to the effects of plants on sulphidic soil and sulphuric soil materials where the tendency was for plants to increase pH level, growth of plants on neutralised sulphuric soil material had little or no influence on pH. The change in pH measured on the neutralised soil induced by organic matter turnover of live plants was dependent on plant type. The pH of the neutralised soil with smaller plants (wheat and lucerne) with smaller organic matter turnover acidified, compared to the treatments with trees (*Allocasurina*, *Eucalyptus* and *Melaleuca*) with bigger organic matter turnover.

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