pH AND CAPILLARY MOISTURE CONTENT RELATIONSHIP IN TOOHEY FOREST SOIL

Soil Report – Toohey Forest

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1. Abstract

Soil pH and moisture content are fundamental properties governing nutrient availability, microbial activity, and organic matter dynamics in forest soils, with their spatial distribution shaped by the interacting influences of parent material, topographic position, and vegetation structure. Understanding these relationships is particularly relevant in highly weathered, acid systems where geochemical constraints limit the range of observable variation.

This report examines the distribution of soil pH and capillary moisture content across a five-site hillslope transect at Toohey Forest, Brisbane, with the aim of characterising their patterns with depth and topographic position and exploring the relationship between them. Soil samples were collected from O, A Upper, A Lower, B Upper, and B Lower horizons at each site, and electrometric pH and gravimetric capillary moisture content were determined in the laboratory.

Results indicated that parent material exerted a dominant control on soil pH, with all recorded values falling within a strongly acidic range between 3.97 and 4.68, consistent with the silica-rich, base-poor Neranleigh-Fernvale bedrock underlying the site. Moisture content generally increased with depth at upper slope sites, consistent with clay accumulation in Lower horizons, while lower slope sites showed more uniform moisture profiles indicating weakly developed profiles over sandstone. An overall weak negative relationship was found between capillary moisture content and soil pH across the transect, with the O horizon displaying the strongest individual relationship.

These findings establish a baseline for the current distribution of soil pH and capillary moisture content along the transect and suggest that topographic position and parent material are primary controls on soil chemistry at Toohey Forest. Further research across multiple transects and seasons would improve understanding of the mechanisms driving these distributions and their broader significance for soil function in dry sclerophyll forest environments.

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2. Introduction

2.1 Background Information – Toohey Forest Study Area

The Toohey Forest study area is a remnant bushland area located in Brisbane, Queensland, embedded within a suburban landscape. The area covers approximately 640 hectares in total, with Brisbane City Council directly managing 260 hectares, and Griffith University owning and managing a significant portion of the forest surrounding its Nathan Campus (TFEEC, 2025).

The underlying geology of Toohey Forest is dominated by metamorphic rocks principally quartzite, chert, and altered shales belonging to the Neranleigh-Fernvale Beds, which formed approximately 380 million years ago during the Devonian period (TFEEC, 2025). Sedimentary rocks of the Woogaroo Subgroup also occur in the area, originating from fluvial and lacustrine depositions approximately 200 million years ago (Wells & O'Brien, 1994). A notable geological feature of the area is the distinct boundary where horizontal early Triassic-Jurassic sandstones (Woogaroo Subgroup) rest directly on top of the highly tilted Neranleigh-Fernvale metamorphic Beds (Wells & O'Brien, 1994; TFEEC, 2025). These parent materials have undergone repeated cycles of weathering and erosion, and the resulting soils are generally nutrient-poor and acidic, reflecting the base-poor nature of the underlying siliceous bedrock and the progressive loss of base cations through leaching over time (TFEEC, 2025; Warke & Wakgari, 2024).

The landforms of Toohey Forest are shaped primarily by fluvial and hillslope geomorphological processes within the Lower Brisbane catchment (TFEEC, 2025; DETSI, 2021). Three major creek systems serve as the primary drainage pathways toward the Brisbane River, with alluvial soil development along lower gully positions (BCC, 2013). Three main soil types are recognised within Toohey Forest: lithosols, podzolic soils, and alluvial soils (Taresh et al., 2025). The sampling site for this study falls within the Coopers Plains soil landscape, characterised by shallow, rocky lithosols on ridge tops developed on sedimentary and metamorphic rocks that have moderate clay-forming potential (Beckmann et al., 1987). On middle to lower slopes, red-yellow and yellow podzolic soils dominate, with local drainage conditions controlling the degree of iron oxide hydration and hence the colour of the subsoil (Beckmann et al., 1987). At these mid and lower slope positions, the finer-textured B horizon acts as a barrier to vertical water movement, deflecting flow laterally downslope (Beckmann et al., 1987) At these positions, the coarse-textured A horizons are partly attributable to surface transport of material from upslope rather than in-situ pedogenic development, reflecting the influence of hillslope redistribution of soil texture (Beckmann et al., 1987). Their shallow profile, low nutrient status, and limited water-holding capacity impose constraints on vegetation establishment and growth (Beckmann et al., 1987). While the Queensland Globe soil classification overlay (Figure 1) identifies the Toohey Forest area as Dermosol at a broad mapping scale, field observations revealed yellow-coloured subsoils with strongly acidic pH values below 5.5, characteristics consistent with the Kurosol suborder under the modern Australian Soil Classification (Isbell & NCST, 2021).

As a result of the soil and geomorphological characteristics, Toohey Forest supports dry sclerophyll forest vegetation (TFEEC, 2025). The predominant regional ecosystem is RE 12.9-10.17c Open Forest complex (Refer to appendix 8.1, Figure A1). Within the sampling area, vegetation transitions from shrubby dry sclerophyll forest to grassy open woodland moving downslope. Dominant canopy species include *Corymbia citriodora, E. siderophloia, and E. major (*Wardell-Johnson et al., 2007). Canopy structure and leaf litter vary across the transect, with large Eucalyptus baileyana stringybark trees dominating the upper slope positions transitioning to smaller tree species at lower slope positions, influencing the quantity and distribution of organic matter inputs across the soil surface.

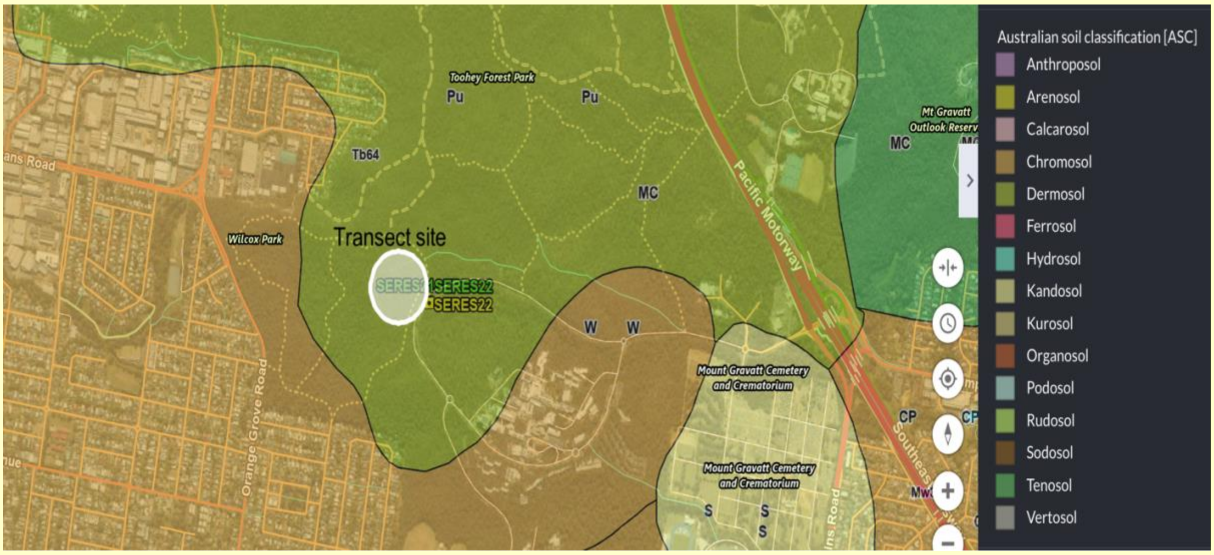

Figure 1, Location of Transect and Queensland Globe Soil Classification

2.2 Soil pH and Capillary Moisture Content (%)

Soil pH, a measure of hydrogen ion activity in the soil solution, is one of the most fundamental chemical properties of soil, governing nutrient solubility and exerting a strong influence on microbial metabolic activity, organic matter decomposition, and the availability of nutrients to plants (Naz et al., 2022). Most microorganisms have an optimal pH range for survival and function, and under strongly acidic or alkaline conditions, bacterial activity is suppressed and the mineralisation of organic matter slows or ceases (Naz et al., 2022). Bacterial diversity tends to peak in soils with near-neutral pH, as acidic conditions impose strong selective pressures that favour specialist acid-tolerant taxa such as Acidobacteria while suppressing broader community diversity, with downstream consequences for nutrient cycling and organic matter decomposition (Tian et al., 2021). Many essential plant nutrients, including phosphorus, calcium, and magnesium, are most available within a moderate pH range, and deviation toward acidity can immobilise these nutrients and delay their release to plants (Warke & Wakgari, 2024). In highly acidic soils, pH values below 5.5 may additionally promote aluminium toxicity, inhibiting root growth and reducing the plant's capacity to absorb water and nutrients (Naz et al., 2022).

In soils such as those found at Toohey Forest, parent material has a major influence on the physical and chemical make-up of soils (Gray & Murphy, 1999). Weathering of silica-rich, base-poor parent rocks such as quartzite and chert, which dominate the Neranleigh-Fernvale Beds underlying Toohey Forest (TFEEC, 2025), releases few base cations, leaving the soil solution relatively acidic (Neina, 2019; Warke & Wakgari, 2024). This tendency toward acidity is further reinforced by organic acid production during the decomposition of organic matter, as humic residues produce carboxyl and phenolic groups that dissociate to release hydrogen ions into the soil solution (Neina, 2019). Cation leaching also plays an important role; under the influence of seasonal rainfall, base cations such as calcium, magnesium, and potassium are progressively displaced from exchange sites and lost from the upper soil profile, driving pH lower over time (Neina, 2019; Naz et al., 2022). In clay-enriched horizons, negatively charged clay particles bind to aluminium and hydrogen ions, displacing calcium and magnesium, which are lost through leaching making the lower horizons more acidic (Warke & Wakgari, 2024).

Capillary moisture content, the proportion of water retained in soil pores against gravitational drainage, is influenced by a range of interacting factors including topographic position, soil texture, porosity, vegetation water uptake, and seasonal variation in rainfall (Yang et al., 2021). Topographic position exerts a particularly strong influence; soils occupying lower slope positions tend to accumulate moisture as both surface and subsurface flows from upslope supplement soil water during and after rainfall events, while soils on upper slopes and ridges drain more freely and experience greater moisture variability (Qiu et al., 2001). Soil texture also plays an important role across the soil profile; coarser sandy topsoils characteristic of podzolic profiles drain rapidly and retain comparatively little capillary water, whereas the denser clay-enriched subsoil horizons found at depth have greater surface area and smaller pore sizes that promote water retention (Beckmann et al., 1987). Vegetation further influences soil moisture distribution through canopy interception of rainfall and the development of coarse root channels, which promote soil macropores and enhance infiltration rates throughout the soil profile (Liu et al., 2022). Organic litter accumulation beneath canopy vegetation directly influences O horizon moisture retention, as the litter acts as an interface between the atmosphere and mineral soil, intercepting and retaining rainfall before it infiltrates to mineral horizons below (Han et al., 2024).

Soil moisture and pH are closely linked across hillslope positions through the combined influence of organic matter decomposition, free drainage, and lateral subsurface flow, with the strength and direction of this relationship varying with topographic position, soil order, and parent material (Garcia-Gamero et al., 2022; Qiu et al., 2001). In the Toohey Forest context, these controls are expected to produce distinct pH and moisture signatures across the five transect sites, reflecting differences in profile development, hillslope position, and parent material. These interacting controls provide the framework for interpreting the distribution of soil pH and capillary moisture content examined in this report.

2.3 Research Aims and Hypotheses

The aims of this report were to: (1) examine the distribution of soil pH and capillary moisture content across the transect at Toohey Forest, (2) explore the relationships between soil pH and moisture content by horizon and by site and (3) consider the factors that may explain the observed patterns of pH and moisture distribution.

Based on the characteristics of Toohey Forest soils and findings from relevant studies, it was hypothesised that: (1) soil capillary moisture content would increase with depth due to greater moisture retention in clay-enriched subsoil horizons; (2) soil pH would decrease systematically with depth due to organic acid translocation and progressive base cation depletion in lower horizons; and (3) the strength and direction of the moisture-pH relationship would vary with topographic position, soil type, parent material and hillslope hydrology across the transect.

3- Methods

Field and laboratory methods were derived from those provided in the Soils and Geomorphology Laboratory Manual (Griffith University, 2026).

FIELD METHODS

3.1 Slope measurements – transect survey

A survey of the site was conducted to produce a transect of the sample collection areas. A Dumpy Level was used to do this survey. The starting point of the transect was at the footpath and the end was downhill towards the creek bed at a total of 121 metres. 11 points were determined from 10 Dumpy Level measurements to construct the transect (Refer to Figure 1 & appendix 8.2, Tables A1 & A2 for raw data). Further details in laboratory manual, p.15-17 (GU, 2026).

3.2 Soil Sample Collection

Soil samples were collected from five points along the transect at horizontal distances of approximately 10, 30, 50, 70 and 90 metres from the start point (refer to Figure 1 & appendix 8.2, Table A 3 for raw data). The location of those points was plotted in Figure 1. A Jarret auger was used to collect samples until the auger could not penetrate further. Samples were taken from the O, A Upper, A Lower, B Upper, and B Lower horizons at each site and stored in sealed zip-lock bags. A change in horizon was declared after change in texture and/or colour.

3.3 – LABORATORY METHODS

3.3.1 Soil pH Method

Electrometric pH was determined using 5g of soil and 25ml of $CaCl2$ solution placed into a 50ml centrifuge tube for each sample. Suspensions were mixed intermittently for 30 minutes. pH meter was turned on and tip cleaned with distilled water, tip was placed in sample for 30 to 60 seconds and pH value was recorded. This was repeated for each sample (GU, 2026). (Refer to appendix 8.3, Table A5 for raw data). Further details in laboratory manual, p.9.

3.3.2 Capillary Moisture Content Method

Approximately 3g of wet grinded soil was weighed was weighed using a precision balance for each sample. Samples were then dried in a 105^0C oven for 24 hours and reweighed. The percentage capillary moisture content was calculated using the following formula:

$$\% \text{ Capillary Moisture Content} = ((W1 - W2) / W2)) \times 100$$

Where W1 = mass of soil (before drying) and W2 = mass of soil dried at 105^0C (GU, 2026). Further details in laboratory manual, p.24-25. (Refer to appendix 8.3, Table A4 for raw data).

ADDITIONAL METHODS

3.4 Soil colour methods

We used the Munsell chart procedure to determine Hue – fundamental colour; Value – light to dark gradient; Chroma – how weak to strong a colour is. Determined dominant colour if there was mottling (GU, 2026). Further details in laboratory manual, p.6-7.

3.5 Soil texture methods

Hand-texturing method – pulverise sample in bowl; put a teaspoon of a sample on our hand. Checked for (feel, sound, ribbon and plasticity), with 6 texture classes matched against a reference table (GU, 2026). Further details in laboratory manual, p.8.

3.6 Particle size analysis methods

Particle size was determined using a combined approach of pipette analysis, wet sieving, and dry sieving. Approximately 20-35 g of soil sample was dispersed in a 1000 ml volumetric cylinder with 10% Calgon and 1M NaOH, sealed, and mixed on an end-to-end shaker for 24 hours. The fine fraction was determined by pipette analysis, where 20 ml amounts were withdrawn at timed intervals corresponding to particle settling sizes and dried in petri dishes. The medium fraction was isolated by wet sieving through a nested sieve stack, and the coarse fraction by dry sieving on a mechanical shaker (GU, 2026). Further details in laboratory manual, p.34-53.

3.7 Soil Carbon

3.7.1 Organic Carbon

Soil organic carbon was estimated using the Loss on Ignition method. Samples were dried at 105^{0}C and transferred into numbered pre-weighed crucibles and weighed to record pre-combustion soil mass. Crucibles were placed on a rack and inserted into a furnace at 550^{0}C for one hour to combust all organic material. Allowed to cool for 20 minutes, crucibles were reweighed to record post combustion soil mass. Soil organic matter content was calculated:

$$\%\ \text{Soil Organic Matter} = ((W1 - W2) / W1) \times 100$$

Soil organic carbon content was then estimated by multiplying the organic matter content by 0.33, reflecting the one-third carbon fraction of organic matter (GU, 2026). Further details in laboratory manual, p.31-32.

3.7.2 Inorganic Carbon

Soil inorganic carbon was measured using a pressure manometer method to detect CO2 produced to detect CO2 produced upon reaction with hydrochloric acid. A set of CaCO3 standards (0.00, 0.25, 1.00, 2.00, and 4.00%) and sample replicates of 2g were weighed into 100 ml Schott bottles. Two millimetres of deionised water were added to each bottle. A small vial containing 5 ml of 10% HCL was carefully placed inside each Schott bottle using metal forceps without spilling the acid. Glycerol was applied to the lid threads and rubber gasket to ensure an airtight seal. Bottles were then tipped to mix the acid with the sample and allowed to react for 30 minutes. A digital manometer fitted with a syringe was zeroed before each measurement and the needle was inserted vertically through the rubber septum of each sealed bottle to record the internal gas pressure (GU, 2026). (Refer to appendix 8.4, Table A 6 for raw data). Further details in laboratory manual, p.27-30.

4. Results

4.1 Slope Measurement – Transect

The transect of the sampling area is presented in Figure 2, with the five sampling sites indicated in orange. The transect spanned a total horizontal distance of 121 metres from the starting point (footpath) to the end point (downhill), with a total change in elevation of -23.55 metres between these points.

Site 1 was located 10m (horizontal) from the start of transect, with a 0.06m increase in elevation (10, 0.06). Site 2 was 30m (horizontal) in to the transect, with a 1.02m decrease in elevation (30, -1.02). Site 3 was 50m (horizontal) in to the transect, with a 3.63m decrease in elevation (50, -3.63). Site 4 was 70m (horizontal) in to the transect, with a 7.75m decrease in elevation (70, -7.75). Finally, site 5 was located 90m (horizontal) from the beginning of the transect having a total decrease in elevation of 13.4m (90, -13.4).

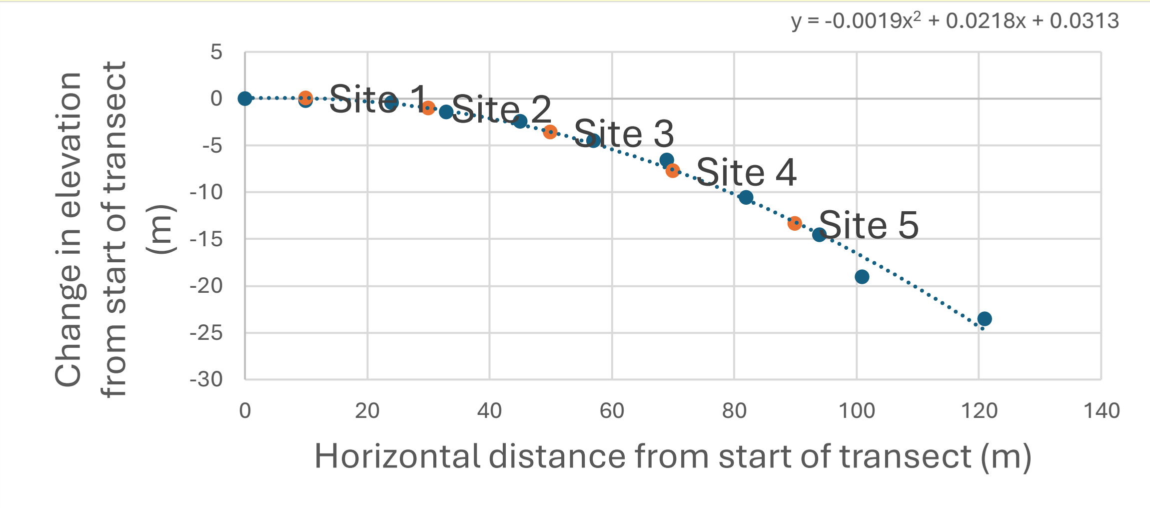

Figure 2. Transect of soil sampling area. The point (0,0) represents the start of the transect, at the footpath. The final point (121, -23.55) represents the furthest point measured downslope.

4.2 Distribution of Soil pH Across the Transect

Soil pH values across all five sites and horizons are presented in Table 1 and illustrated in Figures 3 & 4. All pH values fell within a strongly acidic range, between 3.97 and 4.68,

Table 1. Comparison of Soil pH in each soil sample, with conditional formatting. Darker colours equal lower pH.

HORIZON	SITE 1 pH	SITE 2 pH	SITE 3 pH	SITE 4 pH	SITE 5 pH
O HORIZON	4.68	4.26	4	4.39	4.28
A UPPER	4.12	4.12	4.01	4.36	4.36
A LOWER	4.3	4.59	4.01	4.4	4.25
B UPPER	4.2	3.97	4.05	4.24	4.13
B LOWER	4.09	4.02	3.99	4.07	4.11

A general trend of decreasing pH with depth was observed across most sites (Figure 3 & 4). Site 1 displayed a clear declining trend with depth (R^2-0.53), as did sites 4 and 5 which showed the strongest relationships between horizon depth and pH (R^2=0.74 and 0.74 respectively). Site 2 showed a decreasing trend overall; however, the A Lower horizon recorded an elevated pH of 4.59 before declining in the B horizons, resulting in a weaker fit (R^2=0.16). Site 3 was notably distinct, displaying near-uniform pH values across all horizons (range: 3.99-4.05), with an R^2 of 0.02 indicating no meaningful depth-driven trend at this site.

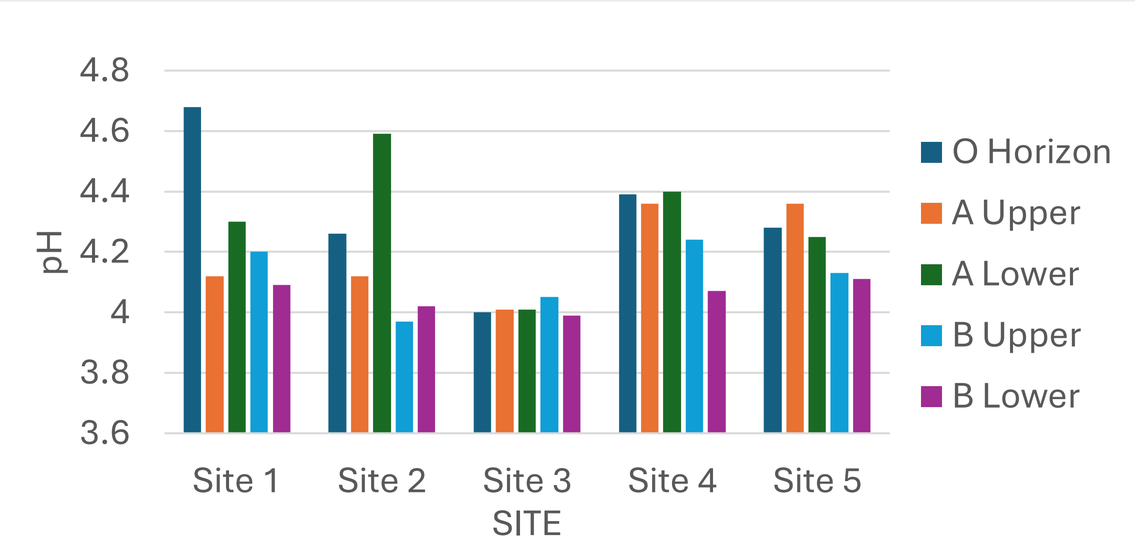

Figure 3. Relationship of pH between soil horizons at each site.

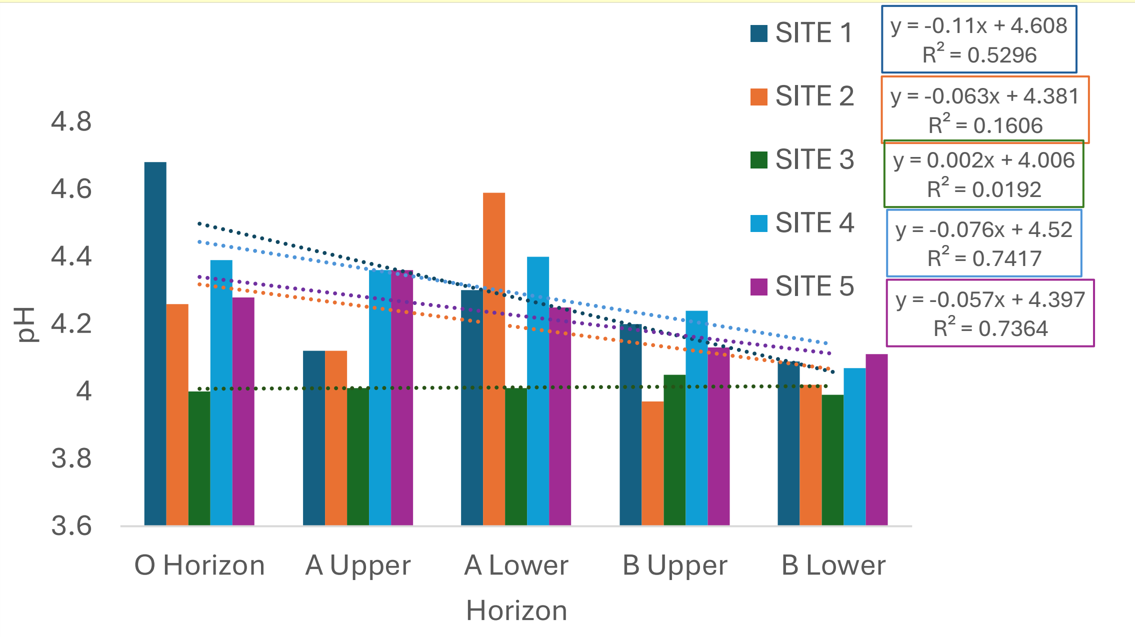

Figure 4. Soil pH for each Soil Horizon at sites 1,2,3,4,and 5, with trendlines.

4.3 Distribution of Capillary Moisture Content Across the Transect

Capillary moisture content values across all five sites and horizons are presented in Table 2 and illustrated in Figures 5 and 6. Moisture values ranged from 1.70% at the O horizon of site 4 to 13.02% at the B lower horizon of site 2, indicating considerable variation across both sites and horizons.

Table 2. Comparison of Capillary Moisture (%) in each soil sample, with conditional formatting. Darker colours indicate a higher capillary moisture (%).

HORIZON	SITE 1 MOISTURE (%)	SITE 2 MOISTURE (%)	SITE 3 MOISTURE (%)	SITE 4 MOISTURE (%)	SITE 5 MOISTURE (%)
O HORIZON	7.25	5.15	11.42	1.70	4.76
A UPPER	5.52	9.47	6.28	5.37	7.69
A LOWER	10.53	6.85	7.27	5.70	6.05
B UPPER	11.19	10.48	7.00	5.55	5.97
B LOWER	10.25	13.02	7.45	5.82	5.53

Sites 1 and 2 displayed clear increasing trends in moisture content with depth, with R^2 values of 0.57 and 0.74 respectively (Figure 6). Site 3 recorded an anomalously high O Horizon moisture content of 11.42% (Table 2); however, the subsequent four horizons displayed an increasing trend from 6.28% in the A Upper to 7.45% in the B Lower, consistent with the general pattern observed at sites 1 and 2, despite the overall negative trendline produced (Figure 6). Site 4 recorded the lowest O horizon moisture content of the entire dataset (1.76%) with the remaining horizons displaying relatively uniform values between 5.37% and 5.82% (Table 2), yielding a shallow positive trend (slope: 0.8427, R^2 = 0.58). Site 5 recorded an O horizon moisture content of 4.76%, rising to a peak of 7.69% in the A Upper horizon before declining progressively to 5.53% in the B Lower horizon (Table 2), producing a near-flat trendline with an R^2 of 0.0008 in Figure 6.

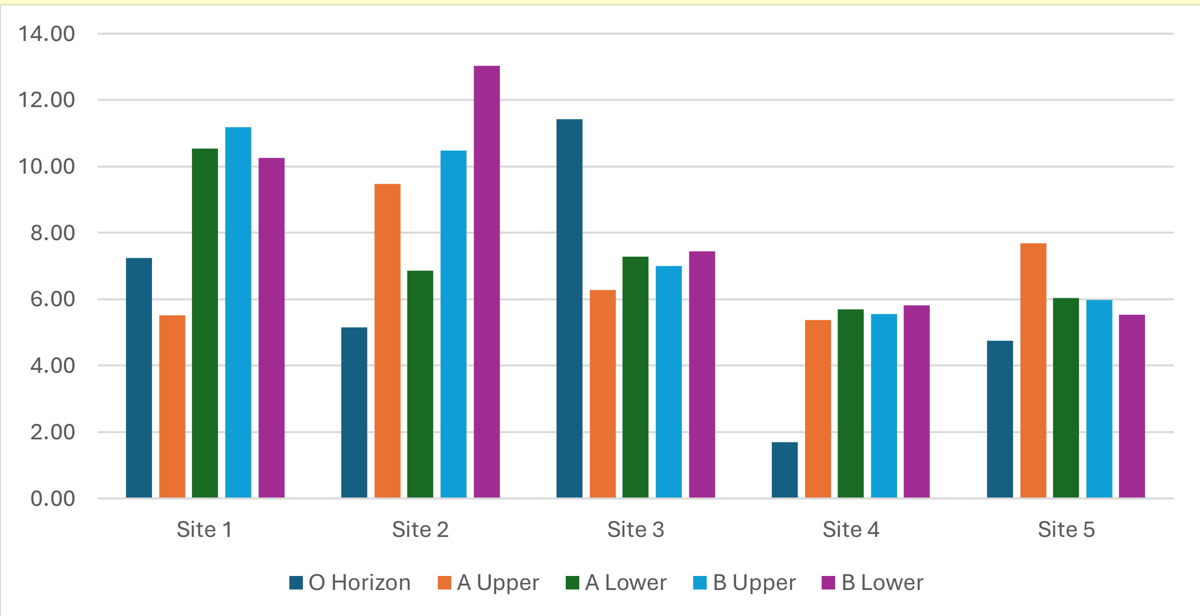

Figure 5. Capillary Moisture (%) between soil Horizons at each site.

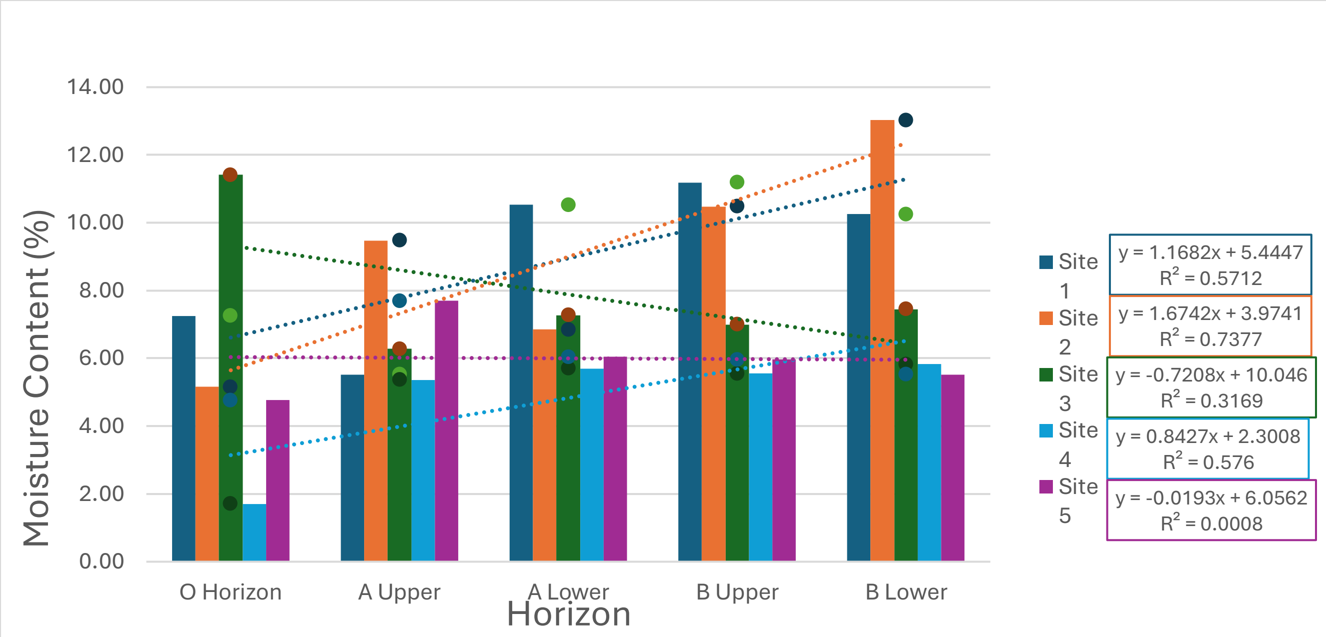

Figure 6. Capillary Moisture Content (%) each Soil Horizon at sites 1,2,3,4,and 5, with trendlines.

4.4 Relationship Between Soil pH and Capillary Moisture Content

The relationship between soil pH and capillary moisture content is presented by horizon in Figure 7, by site in Figure 8, and as an overall transect trend in Figure 9.
Across all horizons, a general negative relationship between moisture content and pH was observed, indicating that soil samples with higher moisture content tended to exhibit lower pH values (Figure 7). The O horizon displayed the strongest negative relationship (R^2=0.18), while the A Upper horizon showed the weakest (R^2=0.008).

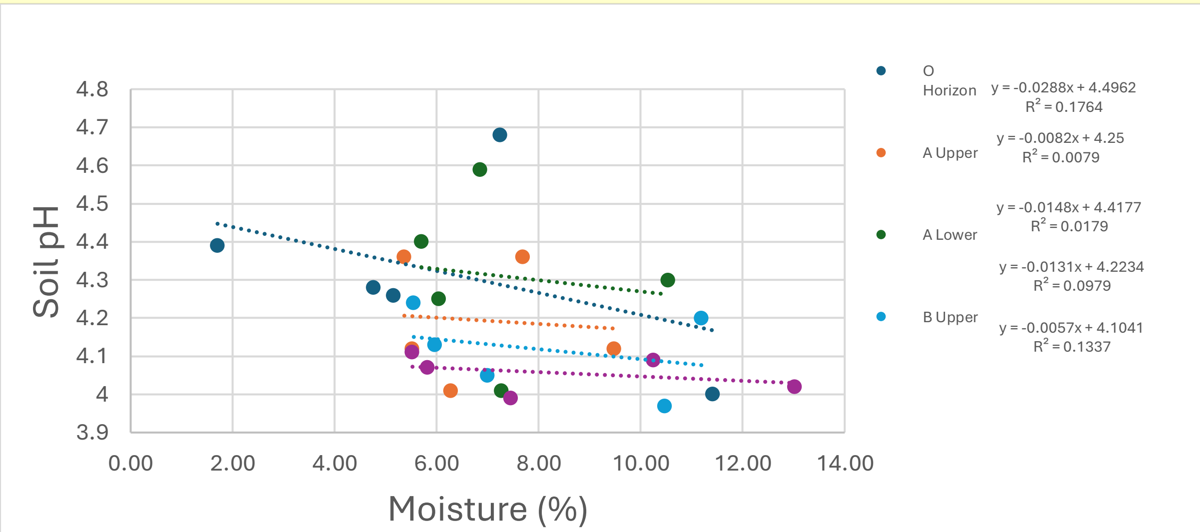

Figure 7. Soil pH & Capillary Moisture Content (%) Relationship for each soil Horizon

When examined by site, sites 1,2,3 and 4 all displayed negative relationships between moisture content and pH, consistent with the overall trend (Figure 8). Site 2 exhibited the strongest negative relationship (R^2 = 0.50), while sites 1,3, and 4 displayed considerably weaker negative relationships (R^2 = 0.05, 0.11, and 0.20 respectively). Site 5 was the only site to display a positive relationship between moisture content and pH, (R^2 = 0.23).

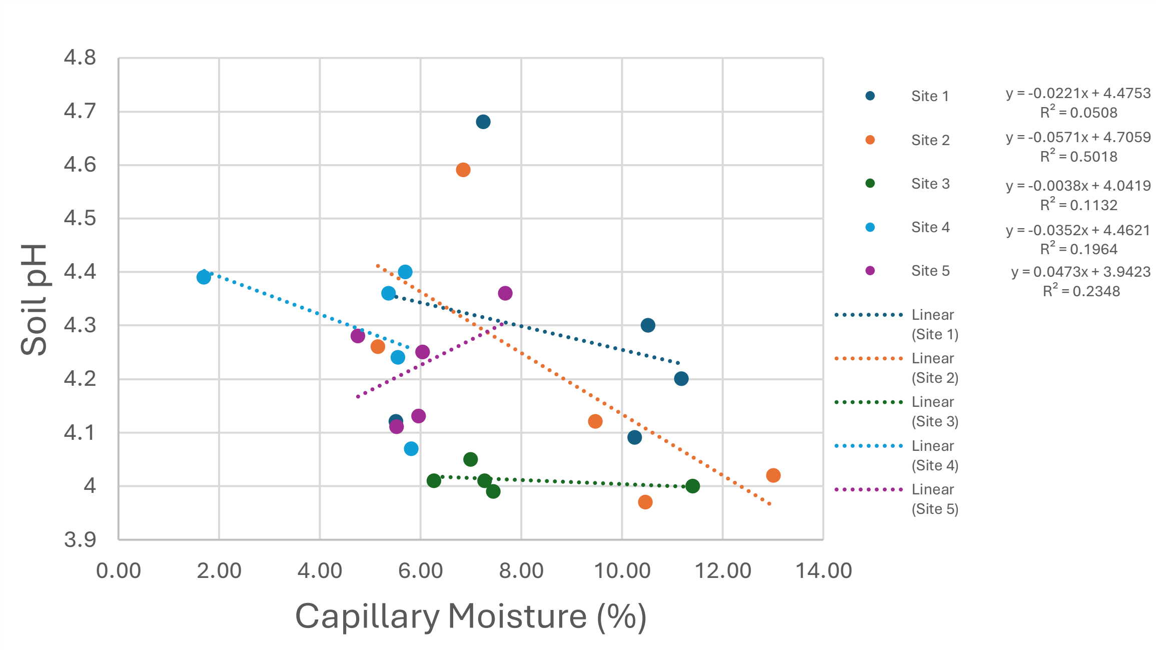

Figure 8. Soil pH & Capillary Moisture Content (%) Relationship for at each site position.

Across all 25 data points, an overall negative relationship between capillary moisture content and soil pH was observed (R^2=0.13, slope = -0.026), indicating a weak but consistent tendency for higher moisture content to correspond with lower pH values across the transect (Figure 9).

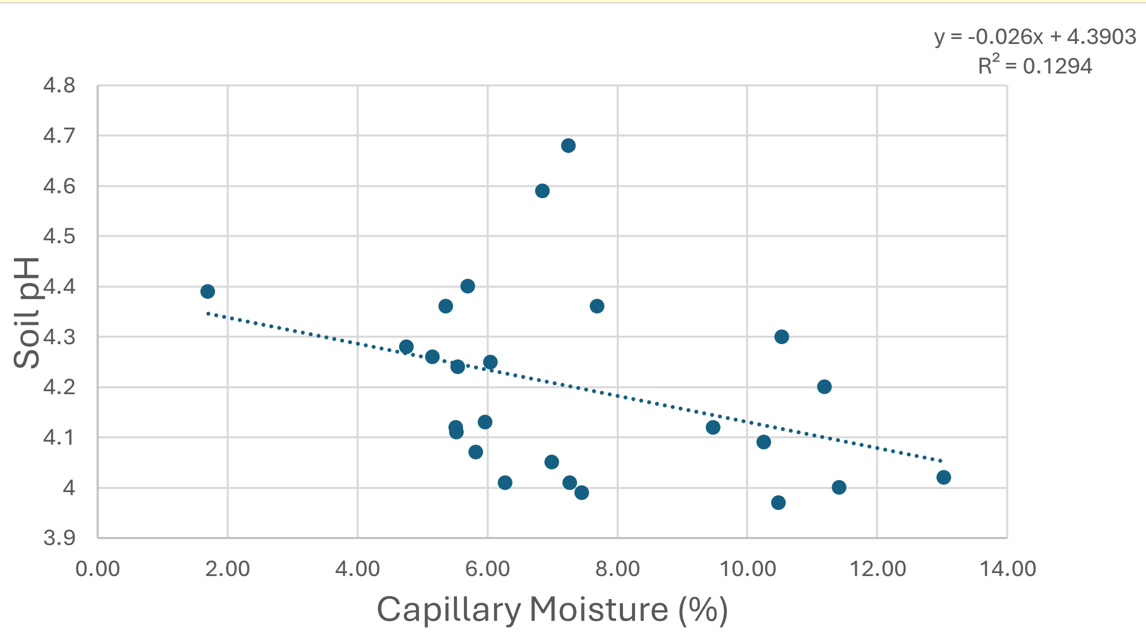

Figure 9. Overall trend throughout each soil profile along transect of Soil pH and Capillary Moisture

5 Discussion

The results reveal strongly to very strongly acidic conditions throughout the entire transect, consistent with the silica-rich, base-poor parent material of the Neranleigh-Fernvale beds underlying the sampling area, which release few base cations upon weathering, leaving the soil solution acidic (TFEEC, 2025; Warke & Wakgari, 2024). The uniformly acidic conditions recorded across all five sites and horizons suggest that parent material exerts a strong baseline control on soil pH at Toohey Forest, with topographic position, vegetation structure, and soil moisture exerting secondary chemical controls on the degree of acidification (Qiu et al., 2001; Garcia-Gamero et al., 2022).

Site 1, at the highest topographic position, displayed the greatest pH variation between horizons and the highest O horizon pH of the entire dataset. The dominance of large Eucalyptus baileyana stringybark trees at the upper slope positions contributes to litter accumulation at the soil surface, enhancing O Horizon moisture retention and providing continuous organic matter input for humic acid production (Han et al., 2024; Neina, 2019). Base cation redistribution through eucalypt bio cycling maintains comparatively less acidic conditions at the surface horizons, consistent with the elevated O horizon pH recorded at site 1 (Lee & Correll, 1978). The elevated O horizon pH at site 1 may also partly reflect the influence of prescribed burning at Toohey Forest, whereby combustion of organic matter releases base cations as ash, raising surface soil pH in surface horizons, with the effect known to decrease with depth (Guinto et al., 2001). The accumulation of clay in lower horizons promotes aluminium hydrolysis, where aluminium ions interact with soil water to release hydrogen ions directly into the soil solution, further driving pH decline with depth (Warke & Wakgari, 2024). Site 2, also at an upper slope position, displayed similar results to site 1, one being increasing moisture (%) down soil horizons, consistent with the freely draining coarser sandy topsoil upper horizons, overlying clay-enriched lower horizons with greater moisture retention capacity (Beckmann et al., 1987). The elevated A Lower horizon pH at site 2 (Table 1) and its low moisture percentage (Table 2), appears to be an outlier that could benefit from further investigation. This outlier introduces variance into the otherwise declining pH with increasing moisture percentage observed across the profile.

Site 3, at a considerably lower elevation to Sites 1 & 2 (Figure 2), displayed near-uniform pH across all horizons (Table 1), contrasting strongly with the depth-driven trends observed at Sites 1 & 2. Field observations confirmed a sandstone outcrop at this location, raising the possibility of a weakly developed tenosol soil profile over sandstone parent material (Isbell & NCST, 2021). The sandstone outcrop at site 3 may act as a physical barrier, trapping fine soil particle material and leaf litter transported laterally from upslope, contributing to its anomalously high O horizon moisture content (Table 2). This interpretation is based on field observation and would benefit from measuring multiple sampling points at this elevation to confirm lateral accumulation. The lower horizons appear to drain freely through the less developed Tenosol profile over sandstone, consistent with the lower moisture values recorded in the lower three horizons at Site 3 relative to Site 1 & 2 (Table 2). The less developed soil horizons and being shallow on sandstone parent material combined with free drainage may homogenise pH conditions across all horizons rather than driving the clear gradient observed at Sites 1 and 2.

Sites 4 and 5, at the lower end of the transect, displayed strong depth-driven pH declines despite the lowest moisture contents across the dataset. Visible sandstone outcrops at both sites and the minimal profile development observed in the field is consistent with Tenosol classification, characterised by weakly developed horizons over sandstone parent material with limited moisture retention capacity (Isbell & NCST, 2021; Qld Govt, 2025). Unlike site 3, which receives lateral litter accumulation, sites 4 and 5 support smaller trees species producing less leaf litter, resulting in the notably low O horizon moisture recorded at site 4 and the near-uniform, freely draining moisture profile observed at site 5 (Table 2). The coarser-textured A horizons at sites 4 and 5, consistent with Beckmann et al. (1987), reflect surface transport of material from upslope rather than in-situ pedogenic development, and the shift from the near-uniform pH at site 3 to a clear depth-driven pH decline at sites 4 and 5 may represent the early stages of the foot slope transition toward alluvial development at lower slope positions (Beckmann et al., 1987).

An overall negative relationship between soil pH and capillary moisture content was observed across all horizons and sites (Figure 9), consistent with greater water availability promoting base cation leaching and organic matter decomposition, both of which increase hydrogen ion concentration in the soil solution (Neina, 2019; Warke & Wakgari, 2024). The O horizon showed the strongest moisture-pH relationship (Figure 7), consistent with it being the primary zone of organic acid production through litter decomposition and the zone most directly influenced by prescribed burning and nutrient bio cycling (Guinto et al., 2001; Lee & Correll, 1978). Site 5 was the only exception, displaying a positive moisture-pH relationship driven by the anomalously high A Upper horizon moisture value (Figure 8, Table 2), removal of this data point reverses the trend to negative, suggesting lateral surface water flow consistent with Beckmann et al., (1987) who noted that fine B horizon particles deflect lateral flow at mid and lower slope positions. While this apparently contradicts the definition of free draining tenosol profiles, it may signal the early stages of clay accumulation in lower horizons, with Tenosols being described as having a light degree of clay content and horizon differentiation, compared to Rudosols which lack clear horizon development (Isbell & NCST, 2021).

The overall weak moisture-pH relationship (R^2 = 0.1294) reflects the narrow pH range across the dataset of less than one pH unit, which limits statistical detectability of moisture-driven variation. This constrained range likely reflects Toohey Forest’s highly weathered, acidic, base-poor quartzite parent material imposing a strong geochemical ceiling on pH (TFEEC, 2025). The shallow, sub-fertile and porous nature of soils developed over these rocks further constrains the pH range observable across the transect (TFEEC, 2025). A single sampling event and subsurface sandstone undulations between sites further limit conclusions, and a broader sampling design across multiple transects and seasons would considerably strengthen understanding of these mechanisms.

6 Conclusions

This report examined the distribution of soil pH and capillary moisture content and their relationship across a five-site transect at Toohey Forest. It was hypothesised that: (1) soil capillary moisture content would increase with depth due to greater moisture retention in clay-enriched subsoil horizons; (2) soil pH would decrease systematically with depth due to organic acid translocation and progressive base cation depletion in lower horizons; and (3) the strength and direction of the moisture-pH relationship would vary with topographic position, soil type, parent material and hillslope hydrology across the transect.

These findings largely supported these hypotheses. Moisture content increased with depth at sites 1 and 2, consistent with clay accumulation in lower horizons, while sites 3, 4 and 5 displayed contrasting moisture profiles consistent with weakly developed Tenosol profiles over sandstone parent material that drain more freely regardless of topographic position. A general decrease in pH with depth was observed at most sites, except for site 3 where a sandstone outcrop, lateral litter accumulation from upslope stringybark trees, and free drainage through the lower profile appeared to homogenise pH conditions across horizons. An overall weak negative relationship between moisture content and pH was confirmed across the transect (R^2 = 0.1294; slope: -0.026), reflecting the combined influence of parent material, vegetation structure, prescribed burning, organic matter dynamics, and topographic position on soil pH independent of moisture content alone.

Key Findings

- Soil pH ranged from 3.97 to 4.68 across the entire transect, indicating strongly to very strongly acidic conditions throughout.
- A consistent negative relationship was observed between moisture content and pH, with the O Horizon showing the strongest relationship (R^2 = 0.1764)
- The moisture content down soil horizons relationship was strongest at upslope sites (Site 1 – R^2 = 0.57, Site 2 – R^2 = 0.74) and weakest at the lowest site (Site 5 – R^2 = 0.0008).
- Site 5 displayed the only positive moisture-pH relationship.
- Site 3 showed little pH variation between horizons (R^2 = 0.019), potentially accumulating leaf litter and finer soil particles in its O horizon from upslope.
- The overall weak R^2 (0.1294) suggests moisture content alone is not a strong predictor of soil pH at Toohey Forest, and that parent material, organic matter dynamics and topographic position could play a greater role.

These results establish a baseline for pH and moisture distribution along this Toohey Forest transect and highlight the importance of topographic position on the dynamics of soil chemistry. Further research across multiple transects and seasons would improve understanding of the mechanisms driving pH distribution in Toohey Forest soils.

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8 Appendix

8.1 Regional Ecosystem Map

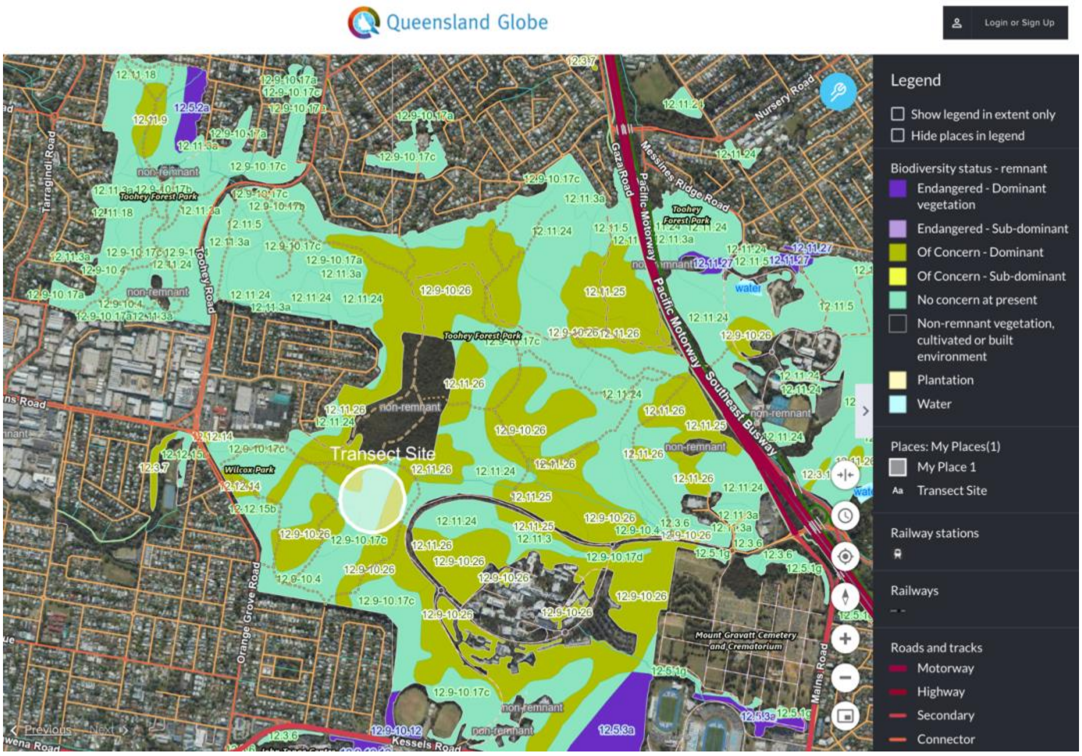

Figure A1. Regional ecosystem mapping of the Toohey Forest study area showing the transect site location (Queensland Globe, 2025).

8.2 Dumpy Level Transect Raw Data

Table A1. Raw Dumpy Level transect readings

Sample Point	Top Wire (m)	Centre Wire (m)	Bottom Wire (m)	Horizontal (m)	Vertical (m)
1A	1.51	1.46	1.41	10	-0.215
1B	1.74	1.675	1.60	14	-0.215
2A	1.18	1.14	1.09	9	-1.02
2B	2.22	2.16	2.10	12	-1.02
3A	0.66	0.60	0.54	12	-2.07
3B	2.73	2.67	2.61	12	-2.07
4A	0.20	0.13	0.07	13	-3.99

Table A2. Cumulative horizontal and vertical distances along the transect

Cumulative Horizontal Distance (m)	Cumulative Vertical Distance (m)
0	0
10	-0.215
24	-0.430
33	-1.450
45	-2.470
57	-4.540
69	-6.610
82	-10.600
94	-14.590
101	-19.070
121	-23.550

Table A3. Horizontal distance and interpolated elevation for each sample site

Sample Site	Horizontal Distance from Start (m)	Elevation Change from Start (m)
Site 1	10	0.059
Site 2	30	-1.025
Site 3	50	-3.629
Site 4	70	-7.753
Site 5	90	-13.397

8.3 Capillary Moisture Content and pH Raw data

Table A4. Raw capillary moisture content data for all sites and horizons. Moisture % values reported at 105^{0}C oven drying temperature.

ID No.	Tin No.	Soil Profile	Tin Weight (g)	Wet Soil W1 (g)	Dry Soil 105°C W2 (g)	Cap. Moisture 105°C (%)
1A	77	O Horizon	11.66	3.02	2.81	7.25
1B	66	A Upper	13.22	2.91	2.75	5.52
1C	130	A Lower	13.58	3.10	2.80	10.53
1D	186	B Upper	11.78	2.93	2.64	11.19
1E	65	B Lower	12.40	2.77	2.52	10.25
2A	40	O Horizon	11.49	3.00	2.85	5.15
2B	31	A Upper	11.73	3.04	2.78	9.47
2C	112	A Lower	9.01	3.06	2.86	6.85
2D	82	B Upper	13.03	3.07	2.78	10.48
2E	33	B Lower	12.06	3.08	2.73	13.02
3A	1	O Horizon	12.72	2.76	2.48	11.42
3B	124	A Upper	13.24	3.06	2.88	6.28
3C	58	A Lower	9.89	3.08	2.87	7.27
3D	44	B Upper	13.07	3.21	3.00	7.00
3E	180	B Lower	11.29	2.93	2.72	7.45
4A	101	O Horizon	13.97	3.05	2.99	1.70
4B	173	A Upper	12.30	3.02	2.87	5.37
4C	32	A Lower	12.22	3.00	2.84	5.70
4D	92	B Upper	13.34	3.00	2.85	5.55
4E	113	B Lower	11.71	3.00	2.83	5.82
5A	83	O Horizon	12.35	3.10	2.96	4.76
5B	95	A Upper	11.76	3.01	2.80	7.69
5C	118	A Lower	13.72	3.02	2.85	6.05
5D	131	B Upper	13.65	2.98	2.82	5.97
5E	72	B Lower	13.76	2.94	2.79	5.53

Table A5. Electrometric pH raw data for all sites and horizons.

ID No.	Sample Name	Soil (g)	Electrometric pH
1A	O Horizon	5.00	4.68
1B	A Upper	4.99	4.12
1C	A Lower	5.05	4.30
1D	B Upper	4.99	4.20
1E	B Lower	4.99	4.09
2A	O Horizon	5.06	4.26
2B	A Upper	4.96	4.12
2C	A Lower	5.05	4.59
2D	B Upper	5.02	3.97
2E	B Lower	5.06	4.02
3A	O Horizon	5.08	4.00
3B	A Upper	5.05	4.01
3C	A Lower	5.05	4.01
3D	B Upper	5.02	4.05
3E	B Lower	5.08	3.99
4A	O Horizon	5.01	4.39
4B	A Upper	5.01	4.36
4C	A Lower	5.15	4.40
4D	B Upper	5.01	4.24
4E	B Lower	5.09	4.07
5A	O Horizon	5.08	4.28
5B	A Upper	5.06	4.36
5C	A Lower	5.10	4.25
5D	B Upper	5.08	4.13
5E	B Lower	5.03	4.11

8.4 Inorganic Carbon Raw Data

Table A6. Inorganic carbon manometer readings for CaCO3 standards and soil sample

Standard	Sample Weight (g)	Manometer Reading (mmWC)
0.00% $CaCO_3$	2.07	67.7
0.25% $CaCO_3$	2.02	148.0
1.00% $CaCO_3$	2.04	262.0
2.00% $CaCO_3$	2.01	172.0
4.00% $CaCO_3$	2.00	1223.0
Sample 2D (B Upper, Site 2)	2.00	33.0
Sample 2C (A Lower, Site 2)	2.00	12.0

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