

Is pasture improvement causing soil acidification in northern NSW?

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Summary. The use of sub-clover in southern NSW and Australia has led to soil acidification. Falls in pH of one unit in 25 to 50 years have been reported on light textured soils by several workers. However, studies of soils in northern NSW have shown the acidification rate to be about half that of southern NSW. Even though acidic soils have been reported in northern NSW, it appears they have acidified naturally, as most occur in high rainfall areas or are formed from parent material high in silica. Pasture improvement does not seem to be associated with soil acidification to the same extent it is in the south of the State, probably because of the more evenly distributed rainfall, perennial pasture species and the longer effectiveness of the soil micro-organisms in capturing and recycling nutrients.

Introduction

Soil acidification occurs naturally and some Australian soils are very acid because they are very old. The effect of agriculture is to accelerate the processes of acidification which occur in nature (16). Acidification mainly occurs through acids produced in the carbon and nitrogen cycles, however, acids are also produced in the S, Fe, Al, Mn and other nutrient cycles (11). In the carbon cycle, acids are produced in association with increases in soil organic matter, the removal of plant and animal products and the transfer of dung and urine to stock camps (18). In the nitrogen cycle, acidification will occur if nitrogen is lost from a system or accumulates in it in a different form from that which was added (10). There are 13.7 million ha having a pH of less than 5.5 in water, or 5.0 in CaCl_2 in New South Wales (11). However, only about one third of this area is in northern NSW mainly on the north coast and tablelands and the Pilliga scrub area (11).

The south of the state has temperate pastures based mainly on subterranean clover, *Trifolium subterraneum*, and annual grasses and it is widely known that sub-clover is a major contributor to soil acidification (5,17,23) and that acidification is greater under annual than perennial pastures (19). It has been estimated that soil acidification may be four to seven times greater in the south than under summer dominant rainfall areas with perennial pastures (4). However, a more recent study by Helyar *et al.* (11) calculated the acid addition to be about double the rate in the north. Crocker and Holford (6) found no significant pH decline on northern soils despite superphosphate (8.6% P, 11.5% S) applications of up to 5 t/ha applied over 40 years.

While most of the reported work on soil acidification has been done in southern Australia (1,2,7,17) this paper compares the effects of superphosphate and pasture improvement on soil acidification in northern *versus* southern NSW. Conditions in southern NSW are reasonably similar to that of southern Australia, and it has been estimated that there is as much land in Victoria, Western Australia and South Australia as in NSW with a pH less than 5 (3).

Soil acidification in southern NSW

The success of pasture improvement in southern NSW has been mainly due to the use of sub-clover, an annual legume ideally suited to the Mediterranean-type environment of this area. While sub-clover is an excellent species for boosting the quantity and quality of pasture and therefore animal production, it has been shown to acidify the soil (2,7,17), and this reduces the long-term productivity of much of Australia's prime agricultural land (17). Sub-clover contributes to soil acidification by increasing soil organic matter, through nitrate leaching and increasing removal of plant and animal products (16).

The build up in soil organic matter leads to acidification mainly through the production of organic acids (16), and also leads to an increase in buffer capacity (the ability of the soil to resist pH change) and in cation exchange capacity. The increase in cation exchange capacity and any export of organic anions in

products and to stock camp sites as waste products, is a measure of H^+ from organic acids that have been added to the soil. The extent of the resulting decrease in soil pH is related to the soil pH buffer capacity. Very light textured soils having a pH buffer capacity about one tenth that of heavy clays (11). Porter (16) calculated that 50 years of pasture improvement on the Crookwell sites had produced an extra 44 t/ha of organic matter in the top 10 cm of soil causing the pH to drop one unit. Cregan *et al.* (5) reported a pH drop of one unit in 25 years, also in the Goulburn-Crookwell area.

Although Ridley *et al.* (18) found that the carbon cycle accounted for 65% of the net acid addition under a fertilized pasture, the nitrogen cycle added 35%. Given nitrogen inputs via biological fixation, NH_4NO_3 , or urea, nitrate losses by run-off and leaching will cause acidification (13). This is especially true of sub-clover which causes nitrate to accumulate during the dry season when plant and biological sinks are inactive. Rapid acidification may occur if the opening wet-season rains remove the nitrate before it is absorbed or denitrified (10).

Acidification in northern NSW

It is well recognised that acidic soils occur in the north (5,8,11,14). However, all these soils appear naturally acidic caused by leaching from high rainfall in the tableland and coastal areas or on sandy soils in the Pilliga area. There have been few reported studies of the effect of pasture improvement on soil pH in the north of the state (6,9; Mears pers. comm., 1991). A recent survey compared 67 paired sites, from improved and unimproved pasture representing soils formed on the three major parent materials, basalt, granite and sedimentary. This showed that there was no significant effect of pasture improvement on soil pH, although 41 of the 67 sites showed a decline of 0.01 to 0.5 pH units. The average pH of the improved sites was 5.02 compared to 5.12 on the unimproved sites when measured in 0.02 M KC1 (1:2.5 soil:solution ratio). The amount or duration of fertilizer was not significant either, although granites showed the biggest pH change.

While three perennial pastures on the north coast and tablelands showed little acidification of soil in the absence of superphosphate, some acidification was occurring with superphosphate producing up to 3.6 kmols H^+ /ha/year (11). At one site, however, 21 kmols were produced. This is an exceptional case though, being a kikuyu pasture heavily fertilized with 340 kg/ha of ammonium sulphate per year.

None of the studies in northern NSW have looked at subsoil acidification and while it has been shown to occur in the south, acidification rates are generally higher in the top 20 cm (17,23). Since acidification of the surface soil is less than in the south, it should also be less in the subsoil. However, sandy soils can be acidified to depth quickly due to low pH buffer capacity.

Is acidification slower in the north than the south?

Evidence suggests soil acidification is slower in the north mainly because of climatic factors, which affect plant species suitability, soil microbial populations and soil formation.

Annual or perennial species

Areas having a distinct dry season, favour nitrate accumulation in the dry season and leaching in the wet season (10,13). This applies to southern Australia with hot dry summers and tropical northern Australia with warm dry winters, but northern NSW has a more even rainfall distribution and this determines pasture suitability. Pasture species differences between the northern and southern regions of NSW is the major reason for differences in rates of acidification. Most southern research work showing soil acidification with pastures is based on annual grasses and sub-clover as the principal or sole legume. On the north coast and tablelands, pastures contain predominantly white clover with associated perennial grasses such as kikuyu, Paspalum, carpet grass (*Axonopus sp.*), phalaris, cocksfoot, fescue and ryegrass. With perennial grass/legume pastures soil nitrate accumulation is probably limited to levels which minimise nitrate leaching, even though similar or greater organic matter accumulation occurs in these environments (13). Ridley *et al.* (19) found acidification to be less under perennial than annual

pastures but carbon cycle acid addition was actually higher under phalaris pasture. The overall reduced acidification was because nitrate leaching was less under phalaris. One practical way of reducing acidification is by more efficiently using soil nitrogen and water (4). Perennial pastures do this especially in the north where there is no distinct dry season. Halving the acid addition rate, possibly under perennial rather than annual pastures, doubles the time for the pH to decrease by one unit (11).

Micro-organisms

Soil micro-organisms are largely overlooked but they comprise an important sink for nutrient elements (21), as well as a source for plant growth by recycling nutrients, accounting for at least as much nutrient cycling (11-57 kg P/ha in the topsoils of high-producing pastures in NZ), as that contained in plants (21). By comparison in Australia, Hutchinson (15) showed a natural *Poa/Themeda* unfertilized pasture to cycle 5 kg P/ha/year, while a highly improved Phalaris/ white clover pasture cycled 40 kg P/ha/year.

As the vast number of micro-organisms live in the soil in a state of near starvation (21), microbial biomass is closely related to root distribution (Hutchinson, pers. comm., 1991). Most of this activity occurs in the surface soil, where surface litter and dung and urine return from grazing animals control the growth of the soil microbial biomass (22). Below this level, microorganisms rely on root exudates and breakdown for their substrate (20) and so with better seasonal conditions for growth in the north the soil biomass acts as an effective nitrate sink and so nitrate leaching and acidification are minimised (10). Increased acidity in the south increases soluble aluminium and this reduces root growth as well as reducing bacterial growth, and so with less substrate for micro-organisms, the whole plant-soil biomass system slows down and leads to decreased production.

Soils

It is well known that poorly buffered light textured soils acidify much more rapidly than more strongly buffered soils (2,6,12). Helyar *et al.* (11) calculated that with equal acid addition rates sandy loam soils can drop one pH unit in 30 years compared with 120 years for clay soils. While there are granitic and light textured soils in the north, there is a larger proportion of heavier soils such as the black earths and cracking clays of the north-west plains. However, the pH decline of 0.012 units per year on granites in the north (6) was only half that of the south. This confirmed calculations by Helyar *et al.* (11) on Duncan and Mears work which showed acid addition rates about half the rate of those in the south.

Research has shown that soil acidification is occurring under clover pasture and many factors affect the rate of soil acidification such as initial soil pH, buffer capacity, clay content, organic matter, aluminium and manganese content plus environmental and management practices (24). However, present evidence suggests that the rate is about half in the summer dominant rainfall areas where perennial pastures predominate and this is supported by figures quoted by (4,6,9,11).

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