MINERALISATION OF SOIL ORGANIC SULPHUR

IN THE TOKOMARU SILT LOAM

A thesis presented in partial fulfilment

of the requirements for the degree of

MASTER OF AGRICULTURAL SCIENCE

in Soil Science

at Massey University

Puntipa Sorn-srivichai

1980

ABSTRACT

Using recently published data, a model of the sulphur (S) cycle for an established pasture, grazed by dairy cattle on Tokomaru silt loam, was constructed by assuming that organic S had reached an equilibrium level. The annual rate of net mineralisation, calculated in the model as 19 kgS ha^{-1}, was the single most important contribution to the plant-available pool of S.

In a field pot experiment involving growing plants under natural rainfall and temperature conditions, the amounts of S mineralised from 6 Tokomaru silt loam soils, differing in their organic matter contents, ranged from 10.9 kgS ha^{-1} to 22.9 kgS ha^{-1}. The relatively high rates of S mineralisation in 2 of the soils collected from the most well-developed pastures suggested that these soils may be approaching the organic matter equilibrium assumed in the model. Such models may therefore be useful in predicting fertiliser inputs to these soils. In contrast, other soils under less well-developed pastures had very much lower mineralisation rates and are apparently still far from equilibrium.

Highly significant relationships were obtained between the amounts of S mineralised in the field and the total S content of the soils. The accumulation of soil organic S within a soil type as indicated by the total S content may be a useful indicator of the approach to equilibrium and hence the extent of net S mineralisation.

The presence of growing plants significantly enhanced S mineralisation in the field in most soils and reduced leaching losses

of S from all soils.

In conjunction with the field pot experiment, a long term field incubation and a series of shorter term incubations (both in the field and laboratory) were conducted to investigate the effects of temperature, moisture content, pH and soil pretreatments on S mineralisation. The amounts of S mineralised in the long term field incubation were found to vary markedly with time. In contrast, the actual levels of soil sulphate during the incubation period were less variable and were highly correlated with the amounts of S mineralised in the field pot experiment. If such incubation techniques are to be used, the amounts of sulphate at the end of the incubation may be a better indication of the ability of a soil to mineralise S in the field than the actual amounts of S released during the incubation.

There were significant relationships between the final levels of sulphate at the end of all the incubation experiments and the total S content, again suggesting that within a soil type, total S content may be used to indicate the ability of the soil to mineralise S.

In all incubation experiments there were negative relationships, for each soil, between the levels of sulphate initially present at the start of the incubation period and the amounts of S mineralised during that period. This indicates some type of 'end product regulation' which may involve sulphatase enzymes.

No significant effects of temperature or moisture content were observed on the rate of mineralisation of soil organic S under the conditions of these incubations.

The addition of lime was found to increase S mineralisation in all soils. The amounts of S mineralised after liming were significantly related to the pH attained in all soils, although in 2 soils they were better related to the amounts of lime added.

ACKNOWLEDGEMENTS

I would like to express my gratitude to:

My supervisors, Mr. Russell Tillman, for his valuable guidance, patience, encouragement and continual assistance throughout all stages of this study, and Dr. P.E.H. Gregg, for his helpful suggestions during the initial period of the study.

Other members of the Department of Soil Science staff, both teaching and technical for their assistance, and to Dianne Syers for the excellent typing of this thesis.

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CHAPTER 1

CHAPTER 1 INTRODUCTION

In recent years the escalating costs of superphosphate and sulphur (S) have focussed attention on the efficiency of use of these fertilisers in New Zealand. Many farmers are already being forced to consider a reduction in the use of superphosphate, and in the future it has been suggested that phosphate rock, which contains very little S, may become more widely used. Since the S requirements of New Zealand pastures in the past have generally been satisfied through the use of superphosphate, this new trend may lead to an increase in the incidence of S deficiencies. In order to avoid this, a sound knowledge of the S cycle in the soil-plant-animal system will be required.

Recent work by Smith (1979), in which the major inputs and outputs of S in a grazed pasture system were measured, has enabled a simple S cycle to be constructed (figure 1.1). The model pertains to an established pasture, grazed by dairy cattle, on Tokomaru silt loam. The following assumptions apply:

(i) The pasture has been established for a large number of years and has received regular topdressing such that the accumulation of organic S has now reached an equilibrium plateau.

(ii) There is no significant pool of adsorbed S in Tokomaru silt loam soils.

(iii) The pasture is a ryegrass-clover mixture producing 10,000 kg ha^{-1} of dry matter annually, with an average S concentration of 0.3 per cent (Metson, 1973). Thus there will be 30 kgS $ha^{-1}year^{-1}$ incorporated in plant tops. Assuming a top-root

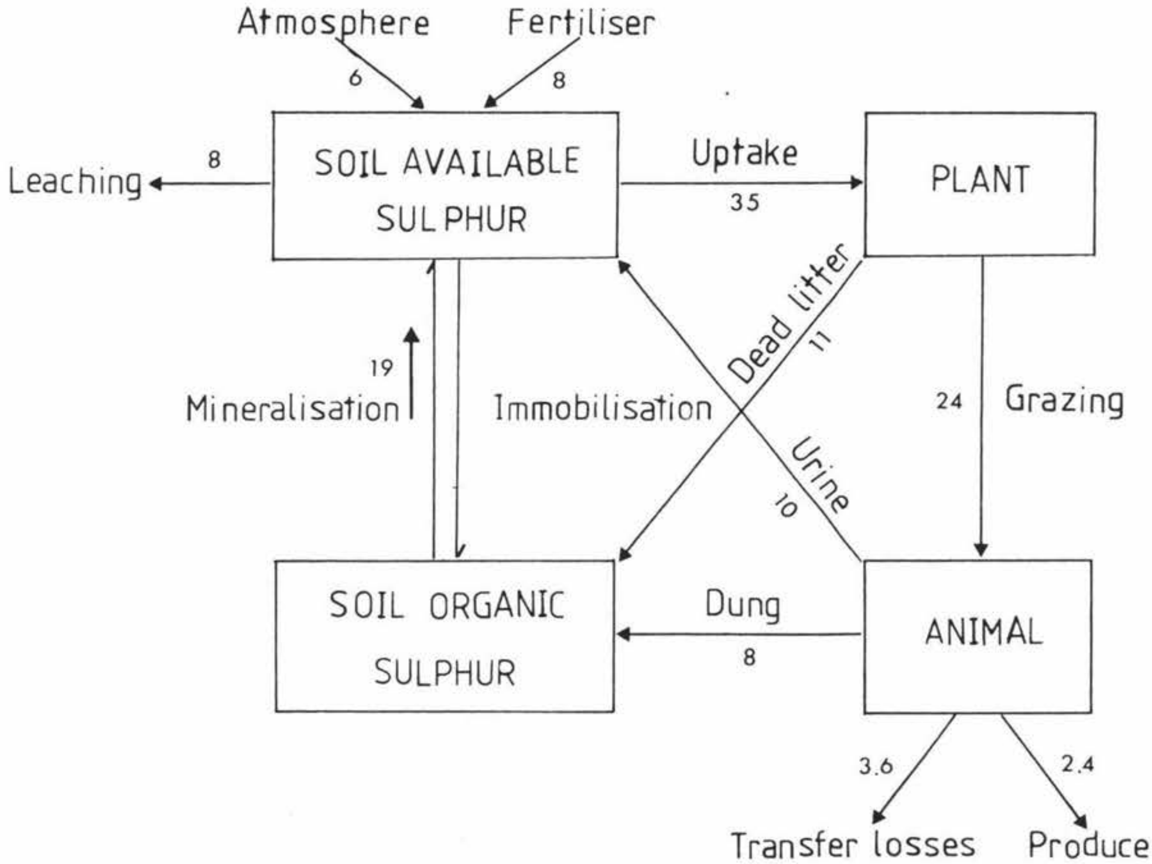

Figure 1.1 Model of a sulphur cycle for an established pasture grazed by dairy cattle on Tokomaru silt loam. (Transfer rates between pools are expressed as kgS ha^{-1}year^{-1}).

production of 3:1 and a root S content of 0.15 per cent (Gregg, 1976), another 5 kgS ha^{-1} will be incorporated annually in roots. The total plant uptake is therefore estimated to be 35 kgS $ha^{-1}year^{-1}$.

(iv) The pasture utilisation is assumed to be 80 per cent thus giving 24 kgS ha^{-1} consumed by animals and the remainder (11 kgS ha^{-1} including root material) returned as dead litter. The S in dead plant residues is assumed to be mostly in organic combination.

(v) Of the herbage S consumed by the dairy cattle (24 kgS $ha^{-1}year^{-1}$), 10 per cent is retained in animal products (During, 1972) and the remainder (21.6 kgS $ha^{-1}year^{-1}$) excreted. A proportion (15 per cent, During, 1972) of excreta is returned to non-grazing areas and is thus lost from the cycle.

(vi) Of the S returned in excreta to productive areas (18 kgS $ha^{-1}year^{-1}$), 60 per cent is in urine (Till, 1975). Approximately 90 per cent of the urinary S is in the form of sulphate which is considered readily available (Walker, 1957). The S in urine returned to the available pool is thus 10 kgS $ha^{-1}year^{-1}$ leaving 8 kgS $ha^{-1}year^{-1}$ in dung and urine returned to the organic pool.

(vii) Leaching losses amount to 8 kgS $ha^{-1}year^{-1}$ (Smith, 1979). These losses could be higher if fertiliser S is applied immediately prior to a prolonged period of rain.

(viii) The annual input of S in rainfall is 6 kgS ha^{-1}. This estimate is based on the amount of S (3 kgS ha^{-1}) deposited in rainfall at the site over 5 months during the winter (Smith, 1979).

(ix) Since soil organic S is assumed to have reached equilibrium, the annual inputs to the organic S pool from dead plant material (11 kgS ha^{-1}) and dung (8 kgS ha^{-1}) must be balanced by loss through mineralisation. The net mineralisation of soil organic S should therefore amount to 19 kgS $ha^{-1}year^{-1}$.

If these assumptions are made, a balance sheet showing the inputs to, and outputs from the available S pool (table 1.1) indicates that without fertiliser addition, there is a net loss of 8 kgS ha^{-1} $year^{-1}$ from the available pool. In order to maintain a constant level of available S, this 8 kgS must be supplied by fertilisers.

It can be seen that mineralisation of organic S contributes to the available pool more than twice as much S as fertiliser and represents about 55 per cent of the total plant requirement. This clearly illustrates the significance of the mineralisation process in a situation where the conditions and assumptions mentioned above apply. Any appreciable variation, in the amounts of S mineralised, from the amount calculated in the model, will have significant consequences on the amounts of fertiliser S required.

It will be reported later in this study that Tokomaru silt loams under established pasture typically have organic S contents of 400 to 500 $\mu g\ g^{-1}$ in the top 8 cm. Since organic S contents generally decrease with the depth of soil (Whitehead, 1964), it is estimated that the top 15 cm of a well-developed Tokomaru soil may contain about 450 $\mu g\ g^{-1}$ of organic S. The annual rate of mineralisation calculated in the model (19 kgS $ha^{-1}year^{-1}$) therefore corresponds to an annual turnover rate of soil organic S of 2.4 per cent. This is in contrast to an annual rate of mineralisation of 1.25 per cent estimated by Walker (1957) and recently repeated by other workers (Tan, 1967; Gregg, 1976; Metson, 1979). Walker (1957) based his calculation upon an assessment of mineral nitrogen (N)

Table 1.1 A balance sheet showing inputs to and outputs from the available S pool in soil (kgS $ha^{-1}year^{-1}$)

INPUTS			OUTPUTS	
Net mineralisation	19		Plant uptake	35
Atmosphere	6		Leaching	8
Urine	10		Total	43
	35	(Deficit = -8)		
Fertiliser	8			
Total	43			

production (Walker et al., 1954) in normal soils of humid temperate climates and their relatively constant N:S (10:1) relationship. According to Walker's (1957) estimate, the annual rate of S mineralisation in Tokomaru silt loams under established pasture would be between 9 and 11 kgS ha^{-1} which is appreciably smaller than the annual turnover rate calculated in the model (19 kgS ha^{-1}).

This large discrepancy may be related to the variation in the equilibrium level of soil organic S. Walker (1957) suggested that the equilibrium level of total soil S under the "best New Zealand conditions" would be 0.12 per cent (or 1200 $\mu g\ g^{-1}$) and that it would take at least 50 years to attain such a level. In this study the relatively low organic S content (400-500 $\mu g\ g^{-1}$) in Tokomaru silt loams under established pasture would indicate that the soils are far from approaching such an equilibrium level. However, recent work by Quin (pers. comm.) on regularly topdressed pastures in Canterbury has shown that soil organic S reached an equilibrium plateau at 400 $\mu g\ g^{-1}$, and this within 25 years. This conflict clearly suggests that there is a need for a knowledge of the actual rate of mineralisation of soil organic S under developed pastures. More investigations are also required to establish any relationships between mineralisation and soil properties so that such properties can be used to predict the rate of mineralisation of soil organic S.

The objectives of this study are:

(i) to determine, under field conditions, the rate of S mineralisation in a number of Tokomaru silt loam soils differing in their organic matter contents;

(ii) to establish the relationships between mineralisation of soil organic S and soil S characteristics in order to use such characteristics to predict the rate of mineralisation; and

(iii) to examine the influence of soil temperature, soil pH and growing plants on the mineralisation of soil organic S.