A decision support model for fertiliser recommendations for grazed pasture

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Abstract

Decision support software for the evaluation of phosphorus (P) and sulphur (S) fertiliser strategies can assist farm consultants and their clients to determine pastoral agriculture fertiliser policies. The underlying dynamic model is based on the P and S cycles in the soil–plant–animal system, including fertiliser inputs and soil- and animal-mediated losses. Initial soil fertility is estimated from the Olsen P and phosphate-extractable organic S soil tests, and recent fertiliser history. In the S sub-model organic S and elemental S pools are considered. Animal production responses to fertiliser are estimated from relationships between soil P and S status, fertiliser inputs, pasture relative yield and stocking rate. Maintenance and economically optimum fertiliser strategies can be automatically calculated or the user can enter their own scenarios. Alternative fertiliser policies can be evaluated in terms of nutrient budgets, soil P and S status, pasture and animal production, and economics.

Keywords: decision support, economics, fertiliser, model, phosphorus, sulphur

Introduction

Fertiliser is a major item of discretionary farm expenditure on pastoral farms in New Zealand, decisions on fertiliser use having a major impact on the short- and long-term economic viability of most properties. Most New Zealand soils are naturally infertile in phosphorus (P) and sulphur (S), and require capital applications of fertiliser to build up soil fertility and lift production (During 1984). To maintain productivity regular fertiliser applications are required to replace the inevitable loss of nutrients through export in animal products, transfer of excreta and soil processes (Cornforth & Sinclair 1982). However, excessive fertiliser use is wasteful economically and may degrade the environment. For sustainable pastoral agriculture a balanced approach to pasture nutrition is required which takes into account soil fertility levels, the losses of nutrients and the economics of fertiliser application.

Until recently, fertiliser recommendation models in New Zealand (Cornforth & Sinclair 1984) were based on static models that balanced fertiliser inputs with nutrient losses. They could not predict the effect of different fertiliser rates on soil fertility and farm production, and did not have an economic component. To overcome these limitations we have developed econometric fertiliser decision support software, based on a dynamic biophysical model of P and S nutrient cycling, pasture and animal production in pastoral farms (Figure 1).

Biophysical model

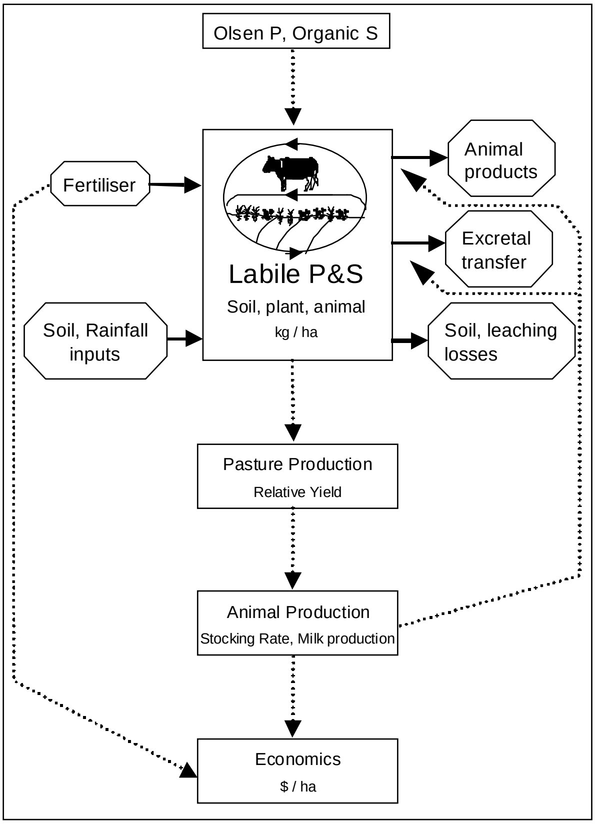
The nutrient cycling sub-models (Figure 2) take into account the major factors, such as stock type, stocking rate, soil group, topography and soil fertility status, that affect nutrient losses and responses. Initial soil fertility is estimated from the Olsen P and phosphate-extractable organic S (Watkinson & Kear 1995) soil tests, and recent fertiliser history. Changes in soil fertility, pasture and animal production are estimated using an annual time step.

The P model is based on a conceptual labile (readily available) P pool, with soil losses proportional to the size of the labile pool, animal-mediated losses proportional to milk production or stocking rate, and a small input from weathering or deep uptake (Metherell *et al.* 1995). The model has been parameterised for dairy, sheep, beef and deer farming, and five topography classes, allowing for product losses and excreta transfer to stock camps and yards. Four soil group categories affect the relationship between Olsen P and labile soil P and the soil loss parameter. The commercially available version of the model only considers additions of soluble P fertiliser and it is assumed that fertiliser P immediately enters the labile pool. However the model can be extended to include reactive phosphate rock (RPR) fertiliser additions to a soil RPR pool with dissolution rates depending on soil and fertiliser properties (Perrott & Metherell 1997).

In the sulphur sub-model organic S and elemental S pools are considered. The organic S soil test determines a base fertility level that is modified by fertiliser derived sulphate. Elemental S is oxidised to sulphate using a region and particle size specific exponential decay rate. Changes in soil S status are based on mineralisation and immobilisation of organic S, a residual value of fertiliser-derived sulphate (Wheeler & Thorrold 1997) and a small net input from rainfall. Leaching and animal losses are not directly estimated.

Responses to fertiliser are estimated from Mitscherlich, or diminishing returns, relationships between soil P and S status, including fertiliser inputs, and relative pasture yield. The effects of P and S on relative yield are combined multiplicatively. Animal production response is estimated from initial pasture and animal production levels assuming a linear relationship between relative pasture yield and milk production or stocking rate. An important assumption is that there will be no change in pasture utilisation or other farm management practices. There is no need to make pasture utilisation or carrying capacity estimates, but the model implicitly calculates, from the initial stocking rate, soil fertility and relative yield estimates, a maximum stocking rate that can be achieved with additional P and S fertiliser.

Figure 1 Links between components of the decision support model. Solid arrows refer to nutrient flows, dotted arrows to information flows.



Economics

To assess the economics of applying varying rates of P and S it is important that the nutrients are correctly costed. On-ground fertiliser costs, including transport and per tonne spreading charges, should be used. A value is placed on both nutrients by considering the price and analysis of two fertilisers, such as superphosphate and sulphur superphosphate. S is a much cheaper nutrient than P. With current prices for superphosphate-based fertilisers (October 1997), and a range in transport and spreading costs from $20 to $100/tonne, P is valued between $1.80/kg P and $2.63/kg P and S between 19c/kg S and 27c/kg S.

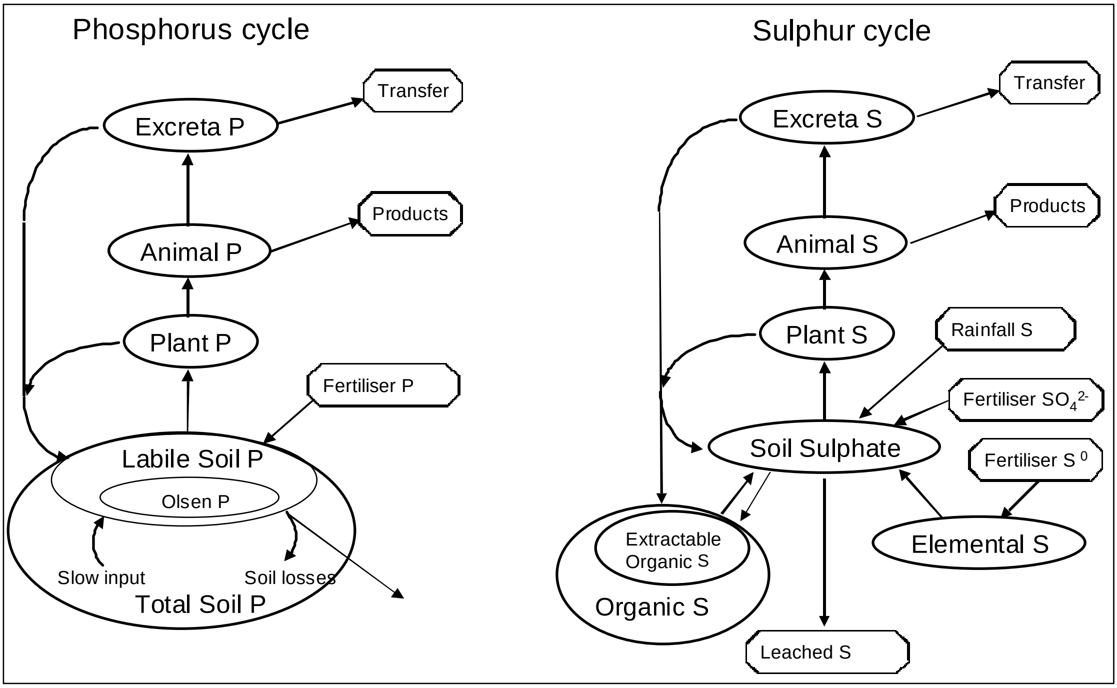
Decisions on fertiliser application strategies must account for both short- and long-term impacts on farm production, cash flows and economic viability. The effect of a fertiliser policy on annual cash flows is shown by the gross margin per hectare calculated from production level and product values, nutrient costs and application rates, and the cost or revenue from a change in stocking rate.

In the assessment of the economics of fertiliser, the contribution of fertiliser to soil fertility, and hence production in future years, must be taken into account (Karlovsky 1966; Godden & Helyar 1980). The long-term value of alternative fertiliser strategies can be assessed using the net present value economic criteria. A time preference discount rate must be chosen to adjust the cash flows from future years into their equivalent present day dollar value. The discount rate should reflect the real rate of return (over and above the effects of inflation) relative to other investment opportunities, but may be adjusted for other factors such as a farmer's planning horizon.

Decision support software

The software, developed by AgResearch in conjunction with users, considers alternative fertiliser policies over multiple farm blocks with different physical and financial properties. Maintenance, target stocking rate and economically optimum fertiliser strategies, with either unlimited or constrained expenditure on fertiliser, can be automatically calculated or the user can enter their

Figure 2 Simplified P and S cycles which are the basis of the biophysical models.



own policies. The maintenance application rate is defined as the annual nutrient requirement to maintain the status quo stocking rate and soil fertility status. The economically optimum strategy allows for the residual value of fertiliser with an algorithm derived on the basis of maximising net present value over an extended time (Woodward 1996). With the constrained expenditure option the model will allocate fertiliser expenditure between farm blocks and to the individual nutrients to give the best economic return, while not exceeding a nominated total fertiliser expenditure in any one year.

Fertiliser policies can be evaluated in terms of nutrient budgets, soil P and S status, pasture and animal production, and their economics. The software can show the effects of capital applications or the withholding of fertiliser for various periods.

Although the decision support model is designed to evaluate fertiliser policies on a site-specific basis, some general conclusions about economically optimum strategies can be drawn. Because S is a cheap nutrient and has a low residual value relative to P, economically optimum strategies generally include S, but in high fertility situations P may be withheld until soil P status declines to the optimum level. In short, it will always pay to ensure that a S deficiency is not limiting production. In low fertility situations the optimal strategy is to apply immediately a capital P fertiliser application (plus S) to increase soil P status to the long run optimum level, followed by the optimum annual maintenance P application. When expenditure is constrained the capital P application will be spread over a few years. Provided that the optimal soil P status is eventually achieved a constrained strategy may be preferable, as it is likely to result in a higher gross margin per hectare in the short term, but have only a small effect on the long-term net present value.

The software is licensed to farm consultants and fertiliser company field representatives by the AgResearch Soil Fertility Service. Future developments will include the inclusion of potassium, magnesium, lime and RPR sub-models.

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