7.0 - nutrient uptake, removal and budgeting

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- nutrient removal
- nutrient budgeting

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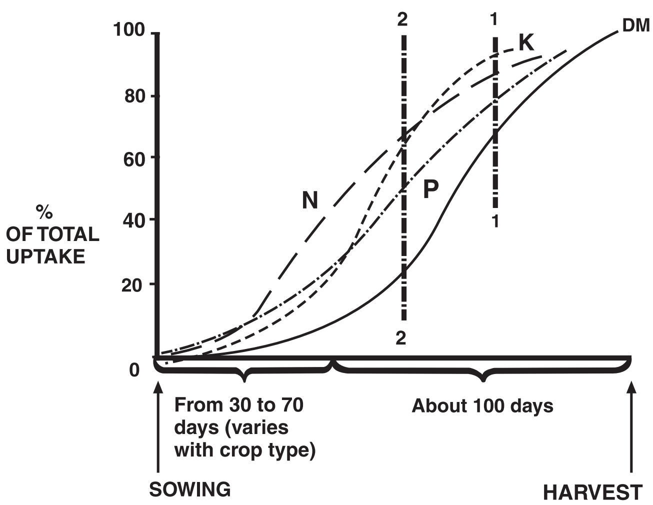
NUTRIENT UPTAKE

The generalised relationship between plant nutrient uptake, from germination through to maturity, is shown in Figure 7.1

Figure 7.1 Generalised Relationship between Plant Growth and Nutrient Uptake.



Plant growth is the main driver of nutrient uptake as indicated by the similarity of the curves in Figure 7.1. However, there can be small deviations from this generalisation. In other words, plant nutrient concentrations are not constant throughout the cycle of plant growth. As illustrated for N, P and K above, most of the plants requirements, particularly for N, are acquired during the vegetative stage. As the plant proceeds to maturity, it simply makes use of previously acquired nutrients, mobilising them from old tissue as required to the growing parts of the plant.

This has important practical implications and explains why nutrients must be available to crops early in the growth cycle if the plant is to achieve its full growth potential.

Pastures are normally grazed at the late vegetative stage when most of the nutrients required for optimal growth have already been acquired, as indicated in line 1 in Figure 7.1. When grazed about half of the standing dry matter is consumed (line 2). The remaining pasture still has an excess of nutrients relative to the accumulated dry matter and can utilise these nutrient reserves during regrowth. However, if the pasture is overgrazed the plant may have no nutrient reserves to commence vigorous regrowth. This is one reason for attempting to keep pastures in a vegetative phase.

NUTRIENT REMOVAL

For crops, and this includes hay and silage, the major pathway for nutrient "loss" from soil is the removal of the crop either off the farm or off that area of the farm. The amounts of nutrients removed by some common NZ crops are given in Table 7.1 and these are typically much larger than other losses from the system such as leaching, run-off, gaseous losses and soil immobilization. For this reason the amounts of nutrients removed in crop can be an approximate guide to determine fertiliser nutrient inputs. The amount of nutrients removed depends largely on the crop yield and this can vary considerably from farm to farm, crop to crop and from year to year. For cereals, the ratio of grain to straw is not constant. For instance, a wheat crop of 4 tonnes/ha does not necessarily remove double the amounts of nutrients, as a crop of 2 tonnes/ha. The data in Table 7.1 requires a further qualification because they do not include the unharvested portions of the plants, such as roots or stubble, which may subsequently be lost from the soil by burning or grazing. Thus losses of nutrients by crop removal may not tell the full story.

The same approach cannot be used in the pastoral situation because the animal returns a large proportion of ingested nutrients back to the land from where it is subject to other losses (Table 7.2) The amounts removed in animal product are small in relation to the other losses. To accurately account for all the inputs and losses of nutrients it is necessary to construct a nutrient budget (Table 7.3).

Table 7.1 Nutrients Removed by Various Crops (kg/ha)

Crop	Yield tonnes/ha	N	P	K (kg/ha)	S	Mg	Ca
Hay / Silage	5.25	260	20	75	15	10	20
Hay (Lucerne)	12	280	30	220	30	35	160
Maize (Silage)	60	300	75	220	25	25	50
Maize (Grain)	12.5	160	40	50	10	20	30
Potato (Main)	15	145	25	190	10	10	5
Potato (Early)	10	125	20	140	5	10	5
Wheat Grain	5	90-110	17	23	8	10	5
Wheat Straw	5.5	39	4	39	7	5	10
Total		129-149	21	62	15	15	15
Barley Grain	5.0	90	17	22	8	5	5
Barley Straw	4.5	36	3	34	6	5	15
Total		126	20	56	14	10	20
Oats Grain	4.0	80+	12	18	6	5	5
Oats Straw	5.0	35	4	40	6	10	10
Total		105+	16	58	12	15	15
Cabbage	50	140	20	125	45	10	20
Tomatoes	49	120	20	150	15	10	5

Table 7.2 The Fate of Nutrients Ingested by Cows

Nutrient	Proportion (%) of Nutrients Ingested			
	Dung	Urine	Milk	Meat
Nitrogen	26	53	17	4
Sulphur	36	54	8	2
Phosphorus	66	0	26	8
Potassium	11	81	5	3

NUTRIENT BUDGETING

AgResearch has developed the software program, "Overseer," for calculating nutrient budgets for N, P, K and S for individual landscape units or farms or blocks within a farm. An example of the output from Overseer, for a dairy farm, is given in Table 7.3. The input data for this example are: 2.7 cows/ha, production 700 kg MS/ha, 1200 mm rainfall, 100 km from the coast, volcanic soil with very low K reserves, Olsen P = 30, K = 10, organic S = 10. Fertiliser inputs 50, 39, 74, 50 N, P, K, S kg/ha respectively. There is no irrigation on the farm and no supplements are used.

Table 7.3 shows the layout of a typical nutrient budget

In this example the fertiliser N, P, K, and S inputs, together with symbiotic N fixation from the legume, are sufficient to make good all the nutrient losses. Consequently the soil is in balance and the soil test levels will remain constant. By definition these fertiliser inputs represent the maintenance requirements for this site.

This example demonstrates the major value of nutrient budgeting. If the balance is positive it means that nutrients are accumulating in the soil. While this is necessary during the development phase, it is not desirable, for economic and environmental reasons, if the soil is currently at the economic optimal soil nutrient levels. Alternatively, a negative balance indicates that the soil is being mined and that given time the soil nutrient levels will decline together with soil productivity.

Table 7.3 An Example of a Nutrient Budget for an Average Dairy Farm.

INPUTS	N	P	K	S
Fertiliser	50	39	74	50
Supplements in	0	0	0	0
Atmosphere	103	0	1	2
Irrigation	0	0	0	0
Slow release[1]	0	3	4	0
OUTPUTS				
Product	58	10	12	4
Supplement out	0	0	0	0
Transfer[2]	54	6	55	0
Atmosphere	14	0	0	0
Leaching	18	0	12	48
Immobilisation[3]	9	26	0	0
BALANCE	0	0	0	0

Notes 1. The amount of nutrient entering the available pool from all soil sources.
2. Transfer to non-productive areas within the land unit being considered.
3. The amounts of nutrient immobilised into the organic matter or, in the case of P, converted into inorganic forms.

This example also demonstrates a further benefit of nutrient budgeting by highlighting where nutrient losses are occurring, and, of these, which mechanisms are more important. This is different for each nutrient. In the example above, the major losses of N are through product removal and transfer to unproductive areas on the farm. For K, the major loss is transfer, but leaching is the major source of loss for S. Reflecting its immobile nature, the major P "loss" is accumulation into organic and inorganic forms in the soil. In fact this is not truly a loss from the system because this immobilised P can largely be reconverted back into available P in the soil. (See Chapter 11).

For both economic and environmental reasons it is desirable to maximise the efficiency of nutrient use, by minimising, if possible, all losses from the pastoral system. As shown in the above example, different strategies are required depending on the nutrient in question. For example, improving the subdivision on the farm may help to reduce transfer loss, but this would primarily affect N and K. Increasing the efficiency of S usage requires concentrating solely on strategies for reducing S leaching.

The amount of S lost through leaching is greater than that for N. Fortunately, sulphate S does not pose the same risk, either in terms of human health or water quality, (see Chapter 13) as does nitrate N and for this reason, leaching losses of S are of little current environmental concern. Further details on managing N leaching losses and P run-off are given in Chapter 18.

An example of a nutrient budget for an average sheep and beef farm is given in Table 7.4. The relevant input data are: steep sedimentary soil, running 7 su/ha, producing 25kg wool /ha and 1600 lambs, Olsen P 10, Organic S 6 and K 10.

Note that relative to a dairy situation, outputs of nutrients as product are less – the operation is less intensive – and the proportional losses due to transfer are much higher. It follows that improving subdivision on a steep sheep and beef farm would be a priority to improve the overall nutrient efficiency.

In this example 50kg/ha, fertiliser N is calculated to be required to maintain the soil N status. In practice this would not be done and as a consequence the clover proportion would increase from low to medium to compensate.

Table 7.4 An Example of a Nutrient Budget for an Average Sheep and Beef Farm.

INPUTS N	INPUTS N	P	K	S
Fertiliser	50	15	18	45
Supplements in	0	0	0	0
Atmosphere	21	0	0	1
Irrigation	0	0	0	0
Slow release[1]	0	3	43	0
OUTPUTS				
Product	8	1	1	1
Supplement out	0	0	0	0
Transfer[2]	37	6	58	5
Atmosphere	6	0	0	0
Leaching	18	0	2	40
Immobilisation[3]	2	11	0	0
BALANCE	0	0	0	0

Notes
1. The amount of nutrient entering the available pool from all soils sources.
2. Transfer to non-productive areas within the land unit being considered.
3. The amounts of nutrient immobilised into the organic matter, or in the case of P, converted into inorganic forms.