# NUTRIENT BUDGETING AND MANAGEMENT ON ORGANIC FARMS

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## Introduction

Nutrient management on organic farms is a major challenge and many of us do not pay it the attention it deserves. If it is ignored at the start of the crop rotation it will be costly to rectify in the future.
Lower crop yields, poor animal performance and stocking rates on farm can occur as a result of poor nutrient management.
Anecdotal evidence suggests that many farms that have entered organic farming have not completed nutrient budgets for their farms and prior to moving into the organic system of farming were returning little or no phosphorus (P) or potassium (K) to their soils. In some of these cases, crop yields are poor because soil reserves have dropped over time due to insufficient nutrient inputs.
In this paper we will address the importance of maintaining soil fertility in relation to what is being removed; what alternatives are out there to replace this loss of nutrients; and what is the potential cost of maintaining or even increasing nutrient levels to improve performance on farms.
"Feed the soil to feed the plant" is often referred to as one of the principles of organic farming. In organic farming we need to look at the "bigger picture" by taking a long term view through a whole farm or farm systems approach. Many organic farms operate mixed systems, so we need to look at all of these systems together.
It is absolutely essential that all nutrients removed in farm produced products are replaced. It is also essential to know current soil fertility status of our soils.
Nutrient management in organic farming systems should be based on regular soil nutrient analysis and nutrient budgets which are used to plan applications of manures, composts and permitted fertilisers.

## Soil Fertility

Good soil fertility is a key component of successful organic farming as the system is totally dependent on having an active and productive soil. The first step to good nutrient management is to test soils and establish the soil fertility status. Soil samples should be taken regularly to check soil fertility levels and monitor soil fertility changes. This is the best way to measure the effect of cropping / nutrient programmes on soil fertility levels over time. It is essential to take good soil samples to ensure accurate soil test results as this will be the foundation to nutrient management on the farm for the next 3 – 5 years. Soil samples should be taken with a suitable soil corer. Take a minimum of 20 soil cores per sample and take to a sampling depth of 10cm. The best times of the year to take soil samples is generally September to December and ensure that there is at least 3 – 6 months between soil sampling and the last application of nutrients
Soil analysis is inexpensive, costing in the region of €1.25/ha/yr when averaged over 5 years. A standard soil test will give the soils fertility status as follows; soil pH, lime requirement, phosphorus (P), potassium (K), magnesium (Mg) together with nutrient advice based on soil sample details. It is essential to take all nutrients into account in order to get the correct nutrient balance in the soil so that applied nutrients are taken up by the growing crop.

## Optimum Levels of Nutrients for Production

### Soil pH

Soil pH is the starting point to ensuring optimum nutrient availability. Correct soil pH is required for a biological active soil with good earthworm activity to break down soil organic matter and deliver good nutrient recycling. Nutrient efficiency will be reduced where the soil pH is below the optimum. To maximise the uptake and availability of N, P & K in organic manures it is recommended to maintain the soil pH between 6.2 and 7.0 (see table 1). Soils should be tested for lime requirement every 5 years to ensure the soil pH is maintained around the optimum for the crop rotation.

***Table 1: Optimum Soil pH for grassland and tillage crops on mineral soils***

| Crop | Optimum Soil pH |
|---|---|
| Grass | 6.3 |
| Grass *(Max. on high molybdenum soils)* | 6.2 |
| Clover | 7.0 |
| Cereals | 6.5 |
| Beet, Beans, Peas, Oilseed Rape | 7.0 |
| Potatoes | 6.0 |
| ***Note: Optimum pH for peat soils pH 5.5.*** <br> ***Source:- Teagasc, 2008*** | |

### Phosphorus (P)

Phosphorus is an essential nutrient particularly in the early stages of plant and root development, providing energy for plant processes such as uptake and transport of nutrients. In grassland, P is essential for the establishment and survival of clovers and rye grasses. Phosphorus has a key role in meat, milk, grain and root crop development; therefore it is critical to apply crop requirements to meet production needs. In many situations P can be the limiting nutrient therefore it is essential to establish soil P levels and build soil P levels for optimum crop and animal production. Soil P is very sensitive to soil pH and is most available in grassland soils at a soil pH of 6.3.

Building soil P reserves is one of the greatest challenges on an organic farm. Soil P levels will fall if P removals are not replaced by organic manures or other nutrient sources.

Aim to build and maintain soil P levels at soil index 3 for optimum production (for grassland 5.1 – 8.0mg/l and for other crops (tillage / horticultural crops) maintain soil P levels at 6 – 10.0mg/l Morgan's Extractant see table 2). Soils maintained at soil index 3 for phosphorus will supply the crop requirements through out the growing season. This will help ensure high yielding cereal crops, early grass growth and good animal performance.

***Table 2: Grassland and other crops soil P & K index***

| Soil P & K index | Soil P (mg/l) | | Soil K (mg/l) |
|---|---|---|---|
| | Grassland | Other crops | Grassland & Other crops |
| 1 | 0.0 – 3.0 | 0.0 - 3.0 | 0 – 50 |
| 2 | 3.1 – 5.0 | 3.1 - 6.0 | 51 - 100 |
| 3 | 5.1 – 8.0 | 6.1- 10.0 | 101 – 150 |
| 4 | > 8.0 | >10.0 | >151 |

**Soil Potassium (K)**

Potassium is an essential nutrient for grain, root and forage crops as these crops have a high K requirement and can remove significant amounts of K at harvest time. To sustain productivity of these crops it is essential to know the soils K status and apply sufficient K levels to replace nutrient off takes. Soil K levels can fall rapidly especially where crop off takes are not replaced. Soil type will have a large effect on soil K supply and rate of decline for example K levels can fall rapidly on a light sandy soil compared to a heavy soil. Aim to build and maintain soil K levels at soil index 3 for optimum production (100 – 150mg/l Morgan's Extractant see table 2). Soils maintained at soil index 3 for K will supply crop requirements through out the growing season. This will help sustain high yielding cereal, root and grass crops.

Maintaining sufficient levels of available soil P & K is essential to good crop and animal production. Soil fertility levels should be maintained by replacing crop / animal P & K removals through correct nutrient budgeting. It remains essential to monitor soil fertility level through regular soil testing and plan nutrient requirements to meet crop yield potential. Good recycling of organic manures will be an essential component to maintaining a productive soil.

**Organic Manure**

A key component of building and maintaining soil fertility in organic farming is a readily available supply of organic manures. Manure recycling will help replenish soil reserves and ensure that annual crop nutrient requirements are satisfied. Organic manures should be applied on a rotational basis depending on soil test results and crop nutrient requirements.
Organic manure nutrient content can vary widely depending on the source of nutrients and it is advisable to have the nutrient content of manures checked through laboratory analysis. Manure application rates should be adjusted in relation to nutrient content and crop requirements. Apply manures in the spring time to maximise the recovery of N especially for manures with high N availabilities (for example cattle slurry). Where liquid manures are applied to tillage soils ensure that they are well agitated, spread evenly and rapidly incorporated (within 4 to 6hrs). Table 3 below shows the total nutrient value for range of organic manures. The monetary values are calculated based on the current price of commercial fertilisers.

***Table 3: Total Nutrient Content & Value (€) of Organic Manures 2010***

| **Organic Manure Type** | **Total N kg/$m^3$ /ton** | **Available N kg/$m^3$ /ton[1]** | **P kg/ $m^3$ /ton** | **K kg/ $m^3$ /ton** | **Value €/ $m^3$ /ton** |
|---|---|---|---|---|---|
| Cattle Slurry | 5.0 | 1.0 | 0.8 | 4.3 | **7.0** |
| Dungstead Manure | 3.5 | 1.4 | 0.9 | 4.2 | **7.50** |
| Farmyard Manure | 4.5 | 1.35 | 1.2 | 6.0 | **9.80** |

[1] *Manure values are calculated based on available N & total P & K. Value of N = €1.27c/kg. P = €1.72/kg, K = €1.00c/kg (Nutrient values based on price of range of fertiliser products)*

## Nutrient advice

Nutrient advice is formulated on the basis of soil fertility levels, stocking rate and crop nutrient requirements. The aim is to apply sufficient nutrient levels to satisfy crop requirements and build soil fertility levels to a target soil P & K index 3. For example at a soil index 3 the nutrient advice is to replace nutrient off-takes to maintain soil fertility. While for example at a soil index 2 the advice is to replace nutrient off takes plus additional nutrient for soil build up to the target index 3 (see P advice for cereals in table 4 below).

### Phosphorus Advice for Cereal crops

Table 4 sets out the P nutrient advice for cereal crops at different soil P indexes. To maintain soil P levels at soil index 3 apply 25kg P/ha see table below. Cereal crops will remove approximately 3.8kg P/ton of cereal grain harvested (plus straw removals) see table 6 below.

***Table 4: P application advice to cereal crops***

| Soil P Index | P Advice kg/ha |
|---|---|
| 1 | 45 |
| 2 | 35 |
| 3 | 25 |
| 4 | None |

### Potassium Advice for Cereal Crops

Table 5 shows the K advice for cereal crops. K advice will depend on the crop and the soil K index. Potassium advice can be adjusted depending on crop yield potential. For example the K advice for a 6t/ha winter wheat crop grown on a soil K index 2 is 75kgK/ha (65kgK/ha plus 10kg K/ha = 75kgK/ha)

***Table 5: Available K advice for cereals where straw is removed (kg/ha)***

| Soil K Index | CROP[1] | | | | |
|---|---|---|---|---|---|
| | Winter Wheat[2] | Spring Wheat[2] | Winter Barley[2] Spring Barley[2] | Winter Oats[3] | Spring Oats[3] |
| 1 | 80 | 85 | 80 | 100 | 95 |
| 2 | 65 | 70 | 65 | 85 | 80 |
| 3 | 50 | 55 | 50 | 70 | 65 |
| 4 | 0 | 0 | 0 | 0 | 0 |

1. ***Assumed crop yields:***
   ***Winter wheat = 5 t/ha  Spring wheat = 4.0 t/ha***
   ***Winter Barley =5.0 t/ha  Spring Barley = 4.0 t/ha***
   ***Winter oats = 5.0 t/ha  Spring Oats = 4.5 t/ha***
   ***Rates above assume no release of K from the soil.***
2. ***For wheat and barley crops: increase or decrease K rate by 10 kg/ha per tonne increase or decrease in grain yield.***
3. ***For oat crops: increase or decrease K rate by 15 kg/ha per tonne increase or decrease in grain yield.***

**Phosphorus and Potassium Off-takes in Cereal Grain & Straw**

Phosphorus and potassium offtakes per tonne of grain (+/- straw) are shown in table 6. Nutrient advice can be tailored to take crop yield potential into account. For example a crop of winter oats with straw removed will remove approximately 3.8kgP/ton and 14.4kg K/ ton of grain.

***Table 6: P & K off takes in cereal crops (kg/ha) per tonne of grain yield***

| | **Straw Removed** | | **Straw not removed** | |
|---|---|---|---|---|
| **Crop** | **P** | **K** | **P** | **K** |
| Winter Wheat / Barley | 3.8 | 9.8 | 3.4 | 4.7 |
| Spring Wheat / Barley | 3.8 | 11.4 | 3.4 | 4.7 |
| Oats | 3.8 | 14.4 | 3.4 | 4.7 |
| ***Source:- Teagasc, 2008*** | | | | |

The P & K nutrient advice for cereals is shown in the tables 4 & 5 as above. When determining the nutrient requirements for a cereal crop you must consider the following: -

1. Soil fertility status (soil P & K index)
2. Crop type (wheat / barley / oats)
3. Yield potential (t/ha)
4. Straw incorporation / removal.

For example a crop of winter oats is been planted with an expected yield potential of 5t/ha. The soil test results show a soil P index 1, soil K index 2 and the straw is baled for animal bedding.
The P advice will be as follows for this crop: The soil fertility is P index 1. The P removed in each tonne of cereal grain plus straw will remove 3.8kg P/t of grain yield (see table 6) Therefore a 5t/ha winter oat crop will remove 19kg P/ha (5 x 3.8kgP/t) in grain & straw at harvest time. The aim is to build soil fertility over time to soil P index 3. To raise soil P index and additional 20kgP/ha must be applied annually. Total crop P requirements will be 39kgP/ha (19 + 20kg P/ha).

The K advice for this crop will be as follows: - The soil test shows a soil K index 2. Table 5 shows that a 5t/ha crop of winter oats requires 85 kg K/ha. This will replace crop K removals (grain & straw) in the harvested crop and build soil fertility levels.
On low fertility sites, P & K should be applied at sowing time and incorporated into the seedbed.

**Meeting Crop Nutrient Demands**

This 5t/ha crop of winter oats require 39kgP/ha and 85kgK/ha. This can be supplied for example by farm yard manure see table 3. Apply 32t/ha of FYM to satisfy the crops P requirements during the growing season. This application will far exceed the crops nutrient requirements for K. This will help build soil K levels which will be beneficial to other crops in the rotation.

## Nutrient Advice for Grassland

Maximising the yield on an organic grassland farm assuming that all fertility levels are good is limited by the performance of clover on the farm. Clover management is not easy and the best grassland managers struggle with stocking rates above 1.5 livestock units per ha (L.U. /ha). Although levels of up to 1.8 L.U. /ha are achievable, the majority of organic farmers in Ireland work at stocking rates from 0.5 to 1.5 L.U. /ha.
Table 7 below shows us what is recommended to apply to grassland for P build up. Ideally all grassland farms should be targeting index 3 to ensure optimum yields, encourage the growth of clovers and ensure that the P levels in the diet of the animals is adequate.

***Table 7: Available P rates (kg/ha) for build-up on mineral soils***

| Soil P Index | Mineral soils [1,2] |
|---|---|
| 1 | 20 |
| 2 | 10 |
| 3 | 0 |
| 4 | No fertiliser P |
| ***1. Mineral soils are defined as soils with less than or equal to 20% organic matter*** | |
| ***2. Peat soils (i.e. soils with more than 20% organic matter) receive only maintenance rates of P*** | |
| ***(Source:- Teagasc, 2008)*** | |

P is removed in animal produce (milk and meat) or as hay or silage. This P must be replaced by applying maintenance rates (i.e. replacing what you remove). Phosphorus can be recycled from concentrate feeds, slurry or approved fertiliser P. Table 8 below quantifies the amount of P removal at different stocking rates in dairy and drystock systems of production.

***Table 8: Grazing: Maintenance rates of soil P to replace off-takes (kg/ha)*** [1, 2,3]

| Grassland stocking rate (kg/ha) of Org N[5] | System[4] Dairy | Drystock |
|---|---|---|
| ≤ 100 | 6 | 4 |
| 130 | 10 | 7 |
| 170 | 14 | 10 |
| ***1. Rates of P fertiliser are based on concentrate usage of zero.*** | | |
| ***2. P for soil build up, as determined by soil Index, should be added to the rates shown above.*** | | |
| ***3. Rates should above refer to maintenance requirements for grazing area only. P requirements for the whole farm depend on the proportion of grazing, hay or silage areas on the farm.*** | | |
| ***4. Where a holding contains a mixture of dairy and drystock enterprises, it is advised that the P rate for all the grazing areas should be based on the dominant enterprise.*** | | |
| ***5 Total annual nitrogen (kg) excreted by grazing livestock averaged over the net grassland area (grazing and silage area). Stocking rate refers to the grassland area only.*** | | |
| ***(Source:- Teagasc, 2008)*** | | |

On most grassland farms it is important to ensure that there is adequate winter feed put in place especially at higher stocking rates. It is of particular importance to organic farmers that try to grow high yielding crops like red clover swards. Large amounts of P and K are removed and must be replaced to avoid significant yield reduction in subsequent years of cropping. Table 9 shows the amounts removed by cutting silage.

***Table 9: Silage and hay: Soil P maintenance requirement to replace off-takes (kg/ha)[1]***

| Soil P Index | First cut[1] | Second or Subsequent cut |
|---|---|---|
| 1 - 3 | 20 | 10 |
| 4 | No fertiliser P | No fertiliser P |
| ***1. P for soil P build-up, as determined by soil index, should be added to rates shown above*** | | |
| ***(Source:- Teagasc, 2008)*** | | |

Potassium (K) is a nutrient that needs monitoring regularly as levels can decline significantly in a short period of time especially in light sandy soils. On light sandy soils apply maintain rates (index 3) annually as it is difficult to build soil K levels on these soils. Table 10 shows the advice on what needs to be replaced by stocking rate and system depending on your soil K index.

***Table 10: Available K for grazing at stocking rate of 170kg/ha Org N[1]***

| Soil K Index | K advice (kg/ha)[2] Dairy | Drystock |
|---|---|---|
| 1 | 90 | 75 |
| 2 | 60 | 45 |
| 3 | 30 | 15 |
| 4 | 0 | 0 |
| ***1. For stocking rates less than 170 kg/ha Org N, decrease rates by 5 kg/ha for each decrease in stocking rate of 40 kg/ha*** | | |
| ***2. K application rates can be calculated by deducting the quantity of K applied in organic fertilisers*** | | |
| (Source:- Teagasc, 2008) | | |

In a silage situation there is no natural manure recycling taking place unlike in a grazing system. As a result the off-takes are significantly higher unless organic manures are applied annually; these are detailed in table 11. Here we are assuming a yield of 5 tons of dry matter per cut.

***Table 11: Available K for silage and hay (kg/ha) this advice assumes a dry matter yield of 5t/ha[1]***

| Soil K Index | First cut silage/hay | 2nd and 3rd cut[2] |
|---|---|---|
| 1 | 175 | 70 |
| 2 | 150 | 50 |
| 3 | 120 | 35 |
| 4 | 0 | 0 |
| ***1. Increase K by 25 kg/ha for each extra t/ha of dry matter (or each extra 5 t/ha of green weight)*** | | |
| ***2. The advice in this column is per cut*** | | |
| ***(Source:- Teagasc, 2008)*** | | |

**Case Study**

In order to try and demonstrate the importance of nutrient budgeting to organic farming, here is a case study. It is a mixed beef and tillage farm. The farm contains 50 ha. All the land is used in the crop rotation. This farmer has not made any conscious decisions in relation to nutrient maintenance or since becoming an organic farmer. The farm includes 25 ha of good mineral soils with suckler cow to beef system stocked at 1.5 L.U per ha, and
25 ha of cereals rotated with the grassland in a 6 year rotation. Tables 12 and 13 show the type of crop rotation being practiced and the average stock numbers on the farm. This situation is not too untypical of what you may find in Ireland today

***Table 12: Crop rotation on case study farm***

| | |
|---|---|
| Year 1 – 3 | Grass/ Clover |
| Year 4 | Winter Oats |
| Year 5 | Winter Triticale |
| Year 6 | Winter Oats |

***Table 13: Average livestock numbers***

| | |
|---|---|
| 18 | Cows |
| 18 | Calves |
| 18 | Finishing cattle |
| 1 | Bull |

The organic nitrogen produced on the grassland area is 108kgs Org N/ha.

**Nutrient Budgeting on this Farm**

In this case an assumption is made that good manure management practices are being completed on farm with for example FYM stored on concrete with effluent collected. Ideally a nutrient budget should be completed for every field or plot on the farm. This is important as there is a problem in some farm systems that nutrients end up being moved from one field to another. Individual field budgets will monitor this.

It is important to try and assess the loss/ gain of nutrients from the farm over a rotation. A nutrient budget is no different from any other budget in that there are receipts and outgoings. The receipts are the nutrients imported onto the farm in the form of feed, seed, grain, straw, slurry, farm yard manure and approved fertilisers. The outgoings on a typical farm include animals, milk, grain, straw or vegetable crops. On many farms some of the products produced by one enterprise are used by another. Anecdotal evidence suggests that many organic farmers believe that by importing in straw to bed animals over the winter period that they are at least importing what's being removed. This case study gives us an opportunity to look at the reality. The situation on this farm is shown in table 14.

***Table 14: Nutrient flow chart for case study farm***

| Nutrient source | Out Flow | In Flow | Remains on farm |
|---|---|---|---|
| 37 tons grain produced | 27 tons | | 10 tons |
| 18 cattle sold each year | 18 cattle | | |
| Straw | | 65 bales | 135 bales |
| Silage | | | 330 bales |
| Seed | | 5.5 tons | |
| FYM | | | |
| Slurry | | | |
| Organically approved fertilisers | | | |

The above table simplifies the following movement of nutrients on this farm.

- 37 tons of grain produced of which 10 tons is kept for feed on farm.
- Straw usage on farm 135 bales produced plus 65 bales purchased locally (200 bales total)
- 330 bales of silage made from 30 acres which are used to feed.
- 5.5 tons of seed purchased to grow crops.
- 18 cattle sold each year (combination of cull cows and finished cattle)

In order to complete a nutrient budget on farm it is important to know what is contained in farm gate sales and imports. Nitrogen, P & K is the main elements. However completing a nutrient budget at farm level is very complex for N, so in this situation we will be look just at P and K. These can be seen in table 15 below

***Table 15: Nutrient content of various farm products***

| **Product (per ton)** | **P (kg)** | **K (kg)** |
|---|---|---|
| Milk | 1 | 1 – 2 |
| Meat | 10 | 2 |
| Grain 1000kgs | 3.4 | 4.7 |
| Grain + Straw (per ton of grain yield) | 3.8 | 9.8 – 14.4 |
| | | ***(Source:- IOTA 2010)*** |

***Table 16: Nutrient flows for case study farm***

| **Nutrient** | **Outflow (P)** | **Outflow (K)** | **Inflow (P)** | **Inflow (K)** |
|---|---|---|---|---|
| Meat | 100 | 200 | | |
| Grain | 92 | 127 | | |
| Straw* | | | 6.9 | 96 |
| Grain seed | | | 18.7 | |
| **Total** | **192** | **327** | **25.6** | **96** |

*0.69kgs P per ton fresh straw & 9.6kgs K per fresh ton straw

As can seen from table 16 above P has declined by 166kgs and K by 231kgs on this farm. Let's look at ways of replacing these nutrients from what we have discussed earlier. This works out at 3.3kgs P and 4.6kgs of K per ha per year. This may appear relatively low, but if levels of P and K are low to begin with this performance will be affected especially in the crops after a relatively short time.

***Table 17: Replacing nutrient options on the case study farm***

| | **Phosphorus (kg)** | **Potassium (kg)** | **Cost €** |
|---|---|---|---|
| Budget summary | -166 | -231 | |
| Options to address shortfall | | | |
| FYM ( import 139 tons) | +166 | +834 | 0 - 1362 |
| Slurry (import 208m$^3$cattle slurry) | +166 | +894 | 0 - 1456 |
| Potassium Sulphate (e.g. Patentkali®)* | 0 | +231 | 855 |
| Ground Rock Phosphate(GRP) (12%P)* | +166 | 0 | 485 |

*prices subject to change, order size and location.

Table 17 slows that the most cost effective way for the case study farm is to import organic manures. This farm needs to spend €23 per ha on FYM. If a combination of Ground Rock

Phosphate and Potassium Sulphate is used the cost changes to €26 per ha, however there is no build up of K included in this figure. If the extra K in the slurry was applied as Potassium Sulphate, this would cost €2454 or an extra €49 per ha.

The case study demonstrates that there is a nutrient loss from the farm. However if the fertility status of the farm is at index 1 or 2 levels for P and K, additional nutrients need to be applied to increase the fertility of the farm. This can be worked out using all the above tables in the paper.

## Conclusion

In this paper we have discussed the importance of proper soil nutrient management. It starts with taking soil samples and finding out the status of the land you are farming. Advice generated from the best available research relevant in Ireland is used to calculate the removals by crop and animal production. It is essential that these nutrients are replaced to ensure the long term productivity of your farm. Where levels are below the optimum for good production, extra nutrients are needed to build up nutrient levels in your soils.

*Take note: - Check whole farm N & P nutrient limits as outlined in SI 101, 2009.*

## References

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