Experience gained while testing soil samples and advising on nitrogen nutrients management in Poland as an extension worker – presentation of "Agronom" software

NUTRIENT MANAGEMENT PLAN

Nutrient management plan concerns appropriate, field and crop specific application of organic and mineral fertilisers in a farm holding while taking account of nutrients dosage and application time as well as soil acidity and fertility in line with assailable nutrient content.
Nutrient management plans are primarily developed with a view to estimate and maximise the use of soil nutrients available in a given farm holding.
Nutrient Management Plan (NMP) comprises two clearly identifiable aspects: agronomic and environmental ones:

Agronomic aspect of NMP is aimed at increased fertilisation efficiency as a result of "farm holding's own fertilising capacity" having been fully utilised. This should result in lower use of mineral fertiliser inputs to produce a crop unit. Furthermore, it also enables the monitoring of soil fertility in order to avoid excessive acidity or nutrient depletion. The former would lead to nutrients accumulation in soil, which is economically ineffective, and the latter would not be beneficial from the soil fertility viewpoint.

Agri-environmental impact of NMP is achieved primarily thanks to fertilisers application precisely according to nutrient demand of a specific crop, which leads to the reduced probability of excessive fertilisation and indirectly limits nutrient losses due to leaching or volatilisation. This is of special importance in animal production operations where animal waste management and the use of organic fertilisers according to state-of-the-art agronomic expertise is a top priority. In those farms, use of mineral fertilisers "supplements" organic fertilising.

THE STRUCTURE OF NUTRIENT MANAGEMENT PLAN

The nutrient management plan comprises the following elements:

1. Determining nutrient demand in line with a target crop and yield on a field to field basis on a given farm, i.e. the amounts of N , P , K intake by a given crop to produce targeted yield.

2. Identification of nutrient sources in line with specific crop requirements on individual fields. The nutrient sources include:

❖ Nutrient sources internal to the field:
- soil itself, depending on the contents of assimilable nutrients
- applied organic fertilisers
- aftercrop plant debris

❖ Nutrient sources external to the field:
- mineral fertilisers

1. Evaluation of nutrient sources internal to the farm:
- determining soil fertility on specific fields

- calculation of nutrients amounts applied to the soil in a given year on specific fields plus organic fertilisers and plant leftovers.

2. Comparing nutrients demand in a given field and the supply of nutrients from the nutrient sources on the farm.

3. Determining the amount of mineral fertilisers for specific crop, field and farm holding.

4. Determining liming demand.

3. Stages of nutrient management plan development:

Stage I includes:

- identification of farm fields,
- plan of arable land and crop structure,
- assessment of soil acidity and assimilable nutrients content (soil fertility),
- target crop yield.

Plan of specific crop fields outlines the field location. It can be best drawn up basing on land register entries and maps. Soil samples for agro-chemical testing and to check nutrient content in soil are performed individually for specific fields.
(show extract from a land register entry and a map)
Specification of fields in a tabular form is an integral part of a fields plan on a given farm holding. The table presents the results of agro-chemical testing, up-to-date soil fertility assessment with a specification of assimilable nutrients and liming requirements for specific crop fields. Thus, they provide basis to determine phosphorus and potassium fertiliser dosage recommendations as well as magnesium fertiliser and liming needs in a given year. The specification is drawn up every 3-4 years basing on subsequent agro-chemical testing results in a breakdown according to fields. Subsequent specification of soil fertility in individual fields provide records to follow fertility changes over years as well as assess the NMP as applied in a farm in a longer term. The specification also enables the plan corrections to be made if the soil nutrients content is to too low and may result in the field production capacity being not fully utilised. If, on the contrary, soil nutrient contents is too high, it indicates unnecessary spending on excessive fertiliser quantities that were used.

Assessment of soil acidity and soil contents of assimilable form nutrients (phosphorus, potassium and magnesium).

Assessment of soil fertility is an important element of diagnostic procedure.

Soil is not uniform in terms of chemical properties. Therefore, weighted average sample must be obtained to determine its profile. Average sample comprises 20-30 single samples (cores) taken at random from evenly distributed locations in the field according to the diagram shown on the screen.

Figure 1. Sampler's moving on the field.

Cores are taken with a special rod placed vertically in the soil turned and taken out with the soil sample removed from the rod and placed in any type of container. Single samples are mixed into a consolidated sample from which an average sample weighting 0.5 kg is taken. Depending on soil variability it represents an area ranging from 0.5 ha to 3.0 ha. On arable land soil sample is taken from the soil 0-20 cm deep whereas, on grassland the surface turf layer must be removed and sample is taken from the soil 5-15 cm deep. Having received laboratory tests results from the agro-chemical testing laboratory, advisor discusses the results with the farmer. Results are presented not only as the colour marked map but also as specific values, which represent nutrient content in the soil in a very accurate way.

(fertilisation recommendations)

(map of fertilisation recommendations)

(Table of figures presenting agro-chemical testing results)

Decision on the soil agronomic category is the first evaluation stage. It is indispensable for the use of limit values during the next stage. Determination of agronomic category is necessary to specify liming requirements and identify soil potassium and magnesium content.

Next, the advisor moves on to prepare a list of crop fields for a given farm.

Table 5 (Criteria to set agronomic soil categories)

Table 6 (Bands of liming demand values)

Table 7, 8 ,9

(Outline of crop fields on a farm) Table 1 (Manual)

Identification of nutrient demand according to specific crops grown on the farm in a breakdown into nitrogen, phosphorus and potassium.

Fertilising demand for a specific crop are the nutrients amounts a given crop needs during vegetation period in order to produce the crop yield target set for that field. In practice, two parameters are necessary to specify nutrient requirements of a given crop (Wp):

- unit intake of specific nutrients: N, P2O5, K20 expressed in kilograms of nutrient to produce 1 tonne of crop (Jp)
- most frequent crop yields (in dt/ha) for a specific type of soil in a given group of fields (P).
- Nutrient demand is calculated by multiplying the parameters specified above :$Wp = Jp \times P$

In order to calculate nutrient demand for crops grown on the farm it is necessary to:

- make a list of crop plants and varieties to be grown on each field in a given
- classify the soil in each field in a specific bonitation class and agronomic use category.

Table 2 (Table of soil grouped according to agronomic use)

- determine the yields expected to be achieved on the farm. Yield forecasts can be best based on the data provided by the farmer and average yields on soils classified in a given category of agronomic use.
- calculate nutrient demand for specific crop according to intake unit indexes and the yields usually achieved on the farm.

Table 3 (Achieved yields and nutrient intake for specific crops)

Example on how nutrient demand for a specific crop is calculated.

Table 4 (nutrient demand of crops in a given farm)

Stage III

3.4. Estimates as to the production volume and nutrients in organic fertilisers produced on the farm.

3.4.1. Annual volume estimation of organic fertilisers production

Most often, the volume of organic fertilisers produced on a farm holding is estimated basing on the number of livestock heads, which is converted into large livestock units (LLU). As agreed, Large Livestock Unit (LLU) is equivalent to 500 kg of live weight of cattle or pigs. It is estimated that 1 LLU generates annually about 10 tonnes of manure and 6 m^3 of liquid manure or 22 m^3 of slurry. If we multiply the number of livestock heads on the farm expressed as LLU in eight units by the annual production of organic fertilisers from 1 LLU, we obtain the total volume of organic fertiliser produced on a given farm. It needs to be stressed that the production volume calculated in this way must be regarded as an estimate to be modified according to conditions specific for a given farm depending on the quantity of bedding used together with the manure or the quantity of water used to maintain hygiene in the livestock quarters and the amount of slurry.

Farm where manure and liquid manure are produced. In order to calculate the amount of manure produced on the farm it is necessary to:

- convert number of livestock heads into LLUs;
- calculate the volume of manure production by the way of multiplying number of animal heads as expressed in LLU by the estimated amount of manure from 1 LLU

example: estimated annual volume of manure and liquid manure produced on a farm holding:

- number of livestock heads : 8 cows, 3 heifers, 4 calves
- conversion of number of animal heads into LLUs

cows: 8 x 1 = 8 LLU,
heifers: 3 x 0,6 = 1,8 LLU
calves: 4 x 0,2 = 0,8 LLU
total number of livestock heads 8 + 1,8 + 0,8 = 10,6 LLU

- estimated volume of manure produced by 1 LLU = 10 tonnes/per year
- estimated volume of liquid manure produced by 1 LLU = 6 m^3
- estimated total volume of manure produced on the farm per year:10,6 LLU x 10 tonnes = 106 tonnes of manure
- estimated total volume of liquid manure produced on the farm per year: 10,6 LLU x 6m^3= about 63m^3 of liquid manure.

In practice, it is sometimes necessary to estimate the weight of manure stored on a prism or a dunghill. To do this, the following co-efficient can be used:
1m^3 of fresh unstacked manure is equivalent to ca 400 kg;
1m^3 of fresh stacked manure is equivalent to ca 700 kg;
1m^3 of stacked, fermented manure is equivalent to ca 900 kg.

Farm holding where slurry is produced. In order to calculate the amount of slurry produced on the farm it is necessary to:

- convert the number of animal heads into LLU
- calculate the volume of slurry production by the way of multiplying the number of animal heads expressed as LLUs by the estimated amount of slurry from 1 LLU.

example: estimated annual volume of slurry produced on a farm holding:

- number of livestock heads : 8 cows, 3 heifers, 4 calves
- conversion of anumber of animal heads into LLUs

cows: 8 x 1 = 8 LLU,
heifers: 3 x 0,6 = 1,8 LLU
calves: 4 x 0,2 = 0,8 LLU
total number of livestock heads 8 + 1,8 + 0,8 = 10,6 LLU

- estimated volume of slurry produced by 1 LLU = 22 m^3/per year

- estimated total volume of slurry produced on the farm per year: 10,6 LLU x 22 m^3 = 233 m^3 of slurry.

The method applied to remove slurry from the farm holding is a key factor while estimating the volume of annual slurry production. As assumed, the unit index of slurry production is 22 m^3 from 1 LLU with the average water consumption. If it is higher or lower, a relevant correction must be made. Slurry production can be also estimated quite accurately if one measures its volume in the tank.

3.4.2. Estimates as to the nutrients value of organic fertilisers.

This paper focuses on organic fertilisers as a source of nutrients for plants that replace specific amounts of mineral fertilisers. However, it must be noted at this point that organic fertilisers are very important in modern farming as they perform certain vital functions, even though they are difficult to measure, for e.g.:

- they improve physical properties of the soil including soil structure, and air and water circulation capacity;
- increase organic matter content , which enhances the soil capacity to absorb and act as a buffer;
- increase carbon and other nutrients content in soil, which directly affects not only the growth of plants, but also stimulates the development of soil micro-organisms that contribute to the mineralisation of organic matter and increase the amount of nutrients available for plants to absorb. Data concerning the chemical composition of specific fertilisers are used in order to estimate the value of nutrients in organic fertilisers. It must be stressed that they are mean values obtained as results of chemical testing of large sample sets /samples of organic fertilisers must be taken on a given farm to be tested for specific nutrients content in order to specify exactly their nutritional values/.

Nutritional value of manure. Determination of the nutritional value of manure involves three indispensable elements:

- nutrients content in the manure;
- amounts of nutrients per 1 tonne of manure;
- coefficients of specific nutrients use in subsequent years.

The use of nutrients coming from manure by the crop plants depends on the time of ploughing and the dampness of soil during vegetation period.

- the consumption of nitrogen in the first year varies from 20 to 40% with the average of 30%, whereas further portion of 20-30 % is used in the second and third year;
- the consumption of phosphorus amounts to 20-25% in the first year and about 60-65% during the rotation period;
- the consumption of potassium ranges between 60-80%, i.e. similar as for mineral fertilisers.

There are some coefficients applied to allow for the conversion nutrient in general form into the active one. Regardless of the application time, they are as follows:

- for nitrogen: 30;
- for phosphorus and potassium: 100.

Nutritional value of liquid manure. Chemical composition of liquid manure depends on animal species and the storing time and manner. Liquid manure is a nitrogen-potassium fertiliser with only trace quantity of phosphorus. The nitrogen and potassium content in the properly stored liquid manure amounts to N- 0,4%, K2O - 0,8% respectively. If the liquid manure is not stored properly, the nitrogen content falls to 0,1% N. As the assimilability of nitrogen and potassium in liquid manure is similar to that of mineral fertilisers, it is a fast working nitrogen-potassium fertiliser.

Nutritional value of slurry. As for the chemical composition of slurry, it varies within a wide band of values depending on the age and use animals, their feeding pattern and the dilution of slurry with water.

Determination of the nutritional value of slurry involves three indispensable elements:

- nutrients content;
- amount of nutrients in $1m^3$ of slurry;
- equivalent amounts of specific nutrients depending on soil quality category and the dates of fertiliser application

As presented in the table above, the heavier the soil, the shorter the period between slurry application date and that of the sowing or planting, and the longer the vegetation period of plants subject to fertilising, the higher the equivalent amounts of nutrients /the better the slurry works/.

3.5. Determination of organic fertilisers dosage for specific fields on a given farm holding

Besides determining the volume of nutrients inputs, the following rules have been applied to specify the organic fertilisers doses:

- excessive doses of organic fertilisers, particularly of liquid manure and slurry, must be avoided as they can affect the crops in an adverse manner:

1- stimulate the growth of weeds because of high potassium content;
2 – result in crustiness of the soil surface;
3 – reduce the sprouting capacity of seeds;
4 – delay the maturation of plants;
5 – the lodging of cereals;
6 – increase the amount of leftovers on pastures;
7 – increase potassium content in fodder up to the level threatening the health of cattle.

- When determining the dosage of organic fertilisers for crop plants, only one nutrient was taken into account, i.a. nitrogen. As for phosphorus and potassium inputs into the soil, their quantities result from the organic fertiliser doses calculated according to nitrogen content;
- when determining the doses for grassland, both nitrogen and potassium were taken account of as their overdosing results also in some negative impact on fodder quality;
- manure is applied for plants with long vegetation period whereas in case of liquid manure and slurry, the application dates should be adjusted in such a way as to ensure the period between application and sowing dates being as short as possible, which will reduce the nutrients loss due to the runoff or volatilisation;
- liquid manure and manure are to be applied during the vegetation period. They should not be applied on fields in winter.
- organic fertiliser dosage must not exceed 170 kg of N calculated per 1 hectare of arable land per year;
- as for slurry, the dosage we accepted as the optimum is the one meeting 50% of the total demand of a given crop for nitrogen and the maximum supply should not exceed 75% of the total nitrogen dosage with the remainder supplied in mineral fertilisers.

3.5.1 Determination of manure doses and application dates.

On arable land, manure is most frequently used for root crops and maize. It can be applied in autumn and spring. If the latter is the case, manure should be spread evenly and ploughed immediately after application.
As for grassland, only composted manure can be applied, i.e. once it has been turned over on a prism once or twice. It can be applied only in spring because of environmental reasons.
As for manure dosages for specific crops, they can be determined as indicative amounts or calculated directly.

Indicative amounts – manure dosage should range within 200-400 dt/ha. The nitrogen content in the dose ranges from 100 to 200 kg of nitrogen respectively, which, once account is taken of the manure nutrient equivalent of 30, means that the nitrogen content in manure dosage equals 30-60 kg of nitrogen in mineral fertiliser, and 30-60 kg P2O5 and 70-140 kg K2O respectively/detailed data are presented in table 15/.
Manure dosages calculated directly – this is a method to specify manure dosages in a more accurate way while taking account of the links with, and the effects of, the application of mineral fertilisers.
Calculations are presented on page 16.
Example:
Crop plant: early harvest potatoes, planned yield 270 dt/ha

- nutrient requirements for the planned yield of 270 dt/ha /table 3/ for nitrogen (dn) N- 95 kg and for the other nutrients: P2O5 - 40 kg, K2O - 200 kg
- Assumed degree of the demand for N to be met (s) - 45%
- Nitrogen content in manure (o) - 0,5 kh N/1 dt
- Fertiliser equivalent of manure (r) - 30
- Manure dosage in dt/ha (D)=dn * s / o * r
  D=95 x 45 / 0,5 x 30 = 285 dt/ha
- The additional input in the dosage is: 84 kg P2O5 and 196 kg K2O
- The remaining 55% of N must be supplied as mineral fertiliser.

3.5.2. Determination of liquid manure doses and application dates.

Liquid manure is suitable for the fertilising of all crops except for the papilionaceous plants. When using slurry one must remember about additional fertilisation application of phosphorus. Recommended liquid manure dosages range between 10-20m³/ha. As for nutrient inputs to the soil, they are as follows 40-80 kg N and 100-200 kg K2O as well as trace amounts of phosphorus. Possible dates of liquid manure application:

3.5.3. Determination of slurry doses and application dates.

When applying slurry on arable land, the following rules must be observed:

- slurry can be best applied on light and medium-light soils late autumn and in spring;
- as for heavy soils, it can be applied in autumn and spring, but, if the land dries up slowly, it is better to apply slurry in spring;
- slurry can be very well applied on stubble field to be covered through skimming.

As for grassland: slurry is the most suitable organic fertiliser.

- it must be applied very evenly;
- it must not be used on dump soils;
- on pastures, the dosage must be reduced by the amount of waste left by animals;

- the grass growth must not exceed 10 cm.

Calculation example:

Grassland used as pasture, yield - 320 dt/ha
- planned nutrient requirement for the yield of 320 dt, for N - 122 kg /dn/ and for other nutrients P_2O_5 - 54 kg, K_2O - 214 kg respectively.
- assumed degree of the demand for N to be met (s) - 75%;
- nitrogen content in the cattle slurry (o) - 3,6 kg N/1m³;
- fertilisation equivalent of slurry on light soils during vegetation period (r) - 70 ;
- slurry dosage in m³ / ha /**D** / = $\mathbf{d_n * s / o * r}$**;**
- D = 122 x 75 / 3,6 x 70 = 36 m³ / ha;
- Additional nutrient inputs in the dosage are: 65 kg P_2O_5 and 133 kg K_2O respectively.

The other quantities of nitrogen and phosphorus must be supplied in mineral fertilisers.

3.6. Determination of mineral fertilisation requirements for the crops on a given farm.

Mineral fertilising needs on specific fields in a farm can be determined thanks to computer techniques or a classic balance method. Mineral fertiliser dosages are determined in the following stages:
- fertilising needs for specific crops need to be determined for nitrogen, phosphorus and potassium;
- it is followed by the estimates as to the nitrogen input sources in the farm and the calculation of nitrogen fertilisation dose;
- next step is to estimate the phosphorus and potassium input sources in the farm and calculate the phosphorus and potassium fertilisation doses.

3.6.1. Estimates as to the nitrogen input sources in a farm holding

Apart from mineral fertilisers, basic nitrogen input sources are:
- organic fertilisers;
- papilionaceous plants grown in the main crop;
- post-harvesting remnants of papilionaceous plants and plants grown as post-harvest crop to be covered while skimming;
- mineralisation of the organic matter in soil;
- mineral nitrogen from the previous year that was not used by plants grown as pre-harvest crop.

3.6.2. Estimates as to the phosphorus and potassium input sources in a farm holding

Major sources of phosphorus and potassium inputs to be considered when determining the doses of mineral fertilisers are as follows:
- soil resources of assimilable forms of the nutrients specified in a given fertility class to be determined;
- organic fertilisers.

3.6.3. Determining the doses of calcium and magnesium fertilisers.

Measurement of soil acidity provides the basis to determine the dosage of calcium fertilisers and to determine the demand for liming on specific fields in a given farm holding. Recommended calcium fertiliser dosages for soils classified in specific categories in respect of liming needs have been determined according to massive field tests performed over many years.

Dolomite (XXXNa wapno węglanowe) is recommended for use on very light and light soils whereas both, XXXwapno węglanowe jak i tlenkowe can be applied on to heavy soil. XXXwapno magnezowe should be applied on acid soils with low magnesium content.

Carbon containing lime is recommended for use on very light and light soils whereas both, carbon and oxides containing lime can be applied on heavy soils. Magnesium lime is recommended for use on acid soils with low magnesium content.