Chapter from the book *Principles, Application and Assessment in Soil Science*
Downloaded from: http://www.intechopen.com/books/principles-application-and-assessment-in-soil-science

Interested in publishing with InTechOpen?
Contact us at book.department@intechopen.com
Mineral Nitrogen as a Universal Soil Test to Predict Plant N Requirements and Ground Water Pollution – Case Study for Poland

Agnieszka Rutkowska and Mariusz Fotyma
Institute of Soil Science and Plant Cultivation – National Research Institute in Puławy
Poland

1. Introduction

Nearly whole (99.7%) territory of Poland, covering about 313 thousand square kilometers is situated in the Baltic Sea basin. This territory is drained by two big rivers Vistula and Odra and seven small rivers flowing directly to this sea. The load of about 145 Gg mineral nitrogen, originating mainly from the agricultural land is discharged yearly by polish rivers to Baltic Sea. Among all countries situated in this catchment Poland contributes in almost 26% to the pollution of Baltic Sea with biogenic substance, nitrogen. In the bulk, this is a serious contribution although calculated for one inhabitant (3.7 kg N per capita) and/or one area unit (4.6 kg N per ha) it belongs to the smallest among other Baltic countries. The big share of agriculture in this load results from the fact that agricultural land covers over 60% of the whole polish territory and constitutes almost 50% of this land in the entire Baltic catchment’s. However, no wonder that Helsinki Commission and UE exert the pressure on our country for limiting the outflow of nitrogen, including the one from agriculture.

Natural farming conditions in Poland are poor, due to prevalence of light, sand-derived soils (60% very light and light soils) and unfavorable climate. The agriculture landscape originates from the period of glaciations. Due to the high diversity of the parent rocks and different geological and pedological processes, a substantial number of soil types and subtypes have developed in Poland. According to the Polish classification system there are 35 different soil types and 78 sub-types. The most common are brown soils, grey brown podsolic soils, rusty soils and podsols soils (Terelak et al. 2000). A much smaller part of land is covered by chernozem soils, rendzina soils, black soils and alluvial soils. Unfertile and acid soils account for 50 to 65 percent of arable land. Soil acidity is linked with the low content of available phosphorus and magnesium and hence constitutes of one of the most limiting factors for soil productivity.

Rainfall mostly occurs during the summer months, and the average annual precipitation varies from 500 mm to 900 mm for the regions of Poland, depending on height above sea level and distance from the Baltic Sea. Average temperature ranges from 7.0 to 9.5 degrees of Celsius. The length of growing season is on average 220 days and is comparable to that in Scandinavian countries. From May to September evapotranspiration in Poland exceeds rainfall, resulting in a continuous water deficit, especially on light soil. Nevertheless, in the early spring the outflow of water from the soil profile is a common phenomena.
Overall, the natural conditions for crop production in Poland are by 30-40% worse in comparison for those in Western Europe. The efficiency of agricultural production is rather low (about 3.5 t·ha\(^{-1}\) cereal grain) but the consumption of nitrogen in mineral (about 65 kg N·ha\(^{-1}\)) and organic (about 30 kg N·ha\(^{-1}\)) fertilizers are comparable with most of the EU countries. As a consequence the balance of nitrogen is positive (about 50 kg N·ha\(^{-1}\)) and the nutrient utilization efficiency is rather low (about 57%). To deal with the problems of nitrogen surplus in the country and bad management of nitrogen fertilizers, Ministry of Agriculture and Rural Development launched in late 90ties the program of soil monitoring for mineral nitrogen.

2. Mineral nitrogen test – the purposes and the needs

Mineral nitrogen, widely understood as the sum of NO\(_3^-\) and NH\(_4^+\) ions, consists of a very small part in the total pool of soil nitrogen. Over 98% of all nitrogen present in soil is in organic forms, not available for plant roots until it is mineralized by microbes into inorganic forms. Mineral forms of nitrogen are very labile and prone to be lost through volatilization and leaching to the ground water. Thus, in the last years the content of mineral nitrogen (N\(_{\text{min}}\)) is commonly recognized as a soil test of nitrogen accessibility for crops and as an indicator for potential pollution of ground water with nitrogen compounds.

Van der Paauw (1963), researching the effects of residual nitrogen was the forerunner for investigations on inorganic N in the soil profile. Later, research in various countries led to N fertilization recommendations based on the linear relationship between N\(_{\text{min}}\) in the rooting zone of the crop at the beginning of vegetation and the optimum N fertilizer rate for the crop. In the Netherlands, N fertilizer recommendations are the function of soil type, whereby “a” and “b” represent a coefficient of the linear relationship between recommendation and N\(_{\text{min}}\) accordingly to the equation (1):

\[
N_{\text{rec}} = a - b \times N_{\text{min}}
\]  
(1)

(as cited in Van Cleemput et al. 2008). In Belgium, an N index method has been proposed. However, this index includes numerous factors, up to 18, as N mineralization, soil compaction, possible N leaching and is calculated as follows (2):

\[
\text{N index} = X_1 + X_2 + X_3 + ... + X_{16} + X_{17} + X_{18}
\]  
(2)

The optimum N fertilization recommendation is calculated accordingly to the equation (3):

\[
N_{\text{rec}} = a - b \times \text{N index}
\]  
(3)

where a and b depend on the cultivar and the destination of the harvested products (Vandendriessche et al., 1992). In France and United States of America, the N balance sheet method was developed. The theoretically recommended N fertilizer doses are based on the balance between the crop requirement minus the amount of N\(_{\text{min}}\) present before sowing plus the mineralization. The residual N\(_{\text{min}}\) in the soil profile at harvest to the mean rooting depth consists of the amount of mineral N that remains in the rooting zone after optimum N fertilization. The practical N fertilization recommendation can further be adjusted according to expected losses. The potential losses are estimated at between 5 and 20%, depending mostly on soil texture (Carter et al., 1974). This method has been applied also in China, with the following approach (4):
Mineral Nitrogen as a Universal Soil Test to Predict Plant N Requirements and Ground Water Pollution – Case Study for Poland

\[
W_{\text{input}} = W_{\text{output}} - \Delta W - (W_n - W_{n+m}),
\]

where \( W_{\text{input}} \) is the N requirement, \( W_{\text{output}} \) – N requirement of the target yield, \( \Delta W \) – volatilized N (N mineralized + subsoil mineral N + dry deposition N + wet deposition N), \( W_n \) - N available before planting, \( W_{n+m} \) – N available after harvest (as cited in Van Cleemput et al., 2008).

In Western Europe, investigations on \( N_{\text{min}} \) as a soil test for fertilizers recommendations have started at the beginning of 1970s (Nommik 1966, Scharpf and Wehrman 1975) and in Poland in the beginning of 1990s (Fotyma 1995, 1996). Of course, for fertilizer recommendations, \( N_{\text{min}} \) test needs a calibration, e.g. critical value for crop nutrition has to be estimated. In pioneer German studies (Scharpf, 1977) by calibrating this test for fertilizer recommendations the simple principle “kilogram for kilogram” has been proposed. It means that each kilogram of mineral nitrogen in the soil profile reveals the fertilizer value equal to one kilogram of nitrogen applied in mineral fertilizers. In Polish approach (Fotyma, 1995) the effect of soil mineral nitrogen has been evaluated by using the \( N_{\text{min}} \) fertilizer replacement value (\( N_{\text{min}} \)RFV). RFV is a multiplying factor for the content of \( N_{\text{min}} \) to a given depth in the soil profile in order to obtain the equivalent amount of nitrogen in mineral fertilizers. When RFV value is equal to 1 then the principle “kilogram for kilogram” comes practically into force. This value depends on crop as well as on soil and climatic conditions and changes in the range 0.6 – 1.1 (Fotyma et al., 2007).

Similarly as in the case of all methods above, evaluation of RFV values is laborious and numerous data from experiments including at least 5-6 nitrogen rates are needed for the process. Moreover, the values reveal a strong variability depending on soil and climatic conditions thus results can be generalized only roughly. The lack of universality of RFV poses a serious drawback in direct application of the \( N_{\text{min}} \) soil test and since late 80ties, another approach gains in popularity. Allowing for the difficulty of evaluating RFV values for fertilizer recommendation, determination of these values has been substituted by establishing the classes of \( N_{\text{min}} \) content in the soil profile, like classes of available phosphorus and potassium. For such calibration of \( N_{\text{min}} \) test the results of soil monitoring for the content of mineral nitrogen offer a good solution.

In the late of 90s, \( N_{\text{min}} \) test starts to be used as a tool for predicting a risk of soil and water pollution by nitrates (Verhagen & Bouma 1997, Enckevort et al. 2002). Nitrates are easily leached down the soil profile to the ground water thus, for environment protection, the content and distribution of nitrates in the soil profile in autumn are of paramount importance. The EU Nitrate Directive (1991) precisely established its content in at 50 mg dm\(^{-3}\) \( \text{NO}_3 \) or 11.3 mg NO\(_3\)-N dm\(^{-3}\) of drinking water. This limit is a reference value for the soil ground water as well, though the ground water with an exception of shallow wells is not directly used for this purpose in general. However direct estimation of nitrate concentration in a ground water is a cumbersome and costly procedure. Therefore, it seems interesting to calculate this concentration based on nitrates content in the bulk of soil.

This paper is focused on the parameterization of \( N_{\text{min}} \) soil test both for fertilizer recommendation and environment protection, using numerous data from the soil monitoring program.

### 3. Materials and methods

The monitoring program for the content of mineral nitrogen has been launched by the Polish Ministry of Agriculture and Rural Development in 1997. Soil samples have been
collected in fixed sites all over the country, twice a year – in spring and autumn to the depth of 90 cm in 0-30, 30-60 and 60-90 cm layers. Soil samples were frozen, and the content of N$_{\text{min}}$ was determined in each layer by the colorimetric method in 1% extract of K$_2$SO$_4$. The content of N$_{\text{min}}$ was expressed in mg NO$_3$-N and NH$_4$- N·kg$^{-1}$ soil dry matter and recalculated into kilogram of N$_{\text{min}}$ in a given soil layer per ha, called further N$_{\text{min}}$ amount. Additionally, at the beginning of this project in all monitoring sites, soil texture has been determined. The technical part of the program, including soil sampling and analysis was entrusted to 17 agrochemical laboratories supervised by the Ministry. The results of analysis were collected in the central database at the Institute of Soil Science and Plant Cultivation – National Research Institute in Pulawy, processed statistically and reported in due course.

Fig. 1. Localization of the monitoring sites in Poland

In this paper, the results for soil samples, collected from about 5100 sites, in the years 1997-2006 are presented as the first stage of the monitoring program. The total number of samples (records) in the data base is about 95000. Each record includes data for three soil layers and two forms of mineral nitrogen NH$_4$-N and NO$_3$-N. The monitoring sites were established on arable land, randomly distributed all over Poland (Fig 1). The distribution of obtained data concerning concentration and content of N$_{\text{min}}$ was far from normality. Therefore, the median
value was used as a characteristic of a mean and percentile as a measure of date distribution. The preliminary statistical analysis shows the significant dependence of $N_{\text{min}}$ content on the soil texture. For this reason, the normative of mineral nitrogen were calculated for each of four textural soil groups: very light (up to 10% of particles below 0.02 mm, light (11 - 20% of particles below 0.02 mm, medium (21-35% of particles below 0.02 mm) and heavy (above 35% of particles below 0.02 mm). Similarly, to five classes of soil reaction and P, K, and Mg content officially used in Poland, five intervals of $N_{\text{min}}$ content were proposed. Each following interval contains 20% of ordered observations and thus five classes of $N_{\text{min}}$ were distinguished - very low, low, medium, high and very high.

4. Results

4.1 Content of mineral nitrogen forms in soil profile
The content of mineral forms of nitrogen has been presented in table 1. The quantity of nitrates and ammonia strongly depends on soil texture, the soil layer and a period of soil sampling. The content of nitrates in soil are higher in autumn than in spring and increases from the very light to heavy soils. The content of nitrate in the upper soil layer is higher in autumn than in spring while the reverse is true for the deepest soil horizon. Ammonia content does not practically differ between the sampling periods and soil textural groups and $\text{NH}_4-N$ is much more evenly distributed in the soil profile irrespective of the season and soil texture. Generally, nitrates content is higher than the content of ammonia.

| N form | Soil layer cm | Spring | | | | Autumn | | | |
|--------|--------------|--------|--------|--------|--------|--------|--------|--------|--------|
|        |              | very light | light | medium | heavy | very light | light | medium | heavy |
| $N_{\text{min}}$ | 0 - 30 | 6,4 | 7,6 | 8,4 | 9,0 | 8,7 | 10 | 10,6 | 11 |
|        | 30 - 60 | 3,8 | 5,5 | 6,1 | 7,1 | 4,7 | 5,4 | 6,1 | 6,6 |
|        | 60 - 90 | 3,4 | 5,1 | 4,8 | 5,4 | 3,3 | 4,2 | 4,0 | 4,3 |
| $\text{NO}_3-N$ | 0 - 30 | 3,3 | 4,4 | 5,5 | 6,5 | 5,6 | 7,1 | 7,8 | 8,3 |
|        | 30 - 60 | 2,0 | 3,5 | 4,0 | 5,2 | 2,9 | 3,7 | 4,1 | 4,9 |
|        | 60 - 90 | 1,9 | 3,4 | 3,2 | 3,8 | 2,0 | 2,7 | 2,5 | 2,8 |
| $\text{NH}_4-N$ | 0 - 30 | 2,7 | 2,5 | 2,2 | 1,8 | 2,4 | 2,2 | 2,0 | 1,6 |
|        | 30 - 60 | 1,4 | 1,4 | 1,5 | 1,3 | 1,4 | 1,2 | 1,4 | 1,1 |
|        | 60 - 90 | 1,1 | 1,3 | 1,1 | 1,2 | 1,0 | 1,1 | 1,1 | 1,0 |

Table 1. Median of mineral nitrogen forms in soil profile depending on soil layer, soil textural group and sampling period in mg N·kg$^{-1}$ soil

4.2 Total amount of mineral nitrogen in soil
For practical purposes, the content of mineral nitrogen, expressed in mg N kg$^{-1}$ soil has been recalculated into the nitrogen amount expressed in kg N·ha$^{-1}$ using standardized value of soil density for selected textural soil groups. Generalized values of soil density for each soil textural group as well as a conversion factor used for recalculation of N content into N amount are presented in table 2.
Soil texture | Soil density [kg m\(^{-3}\)] | Conversion factor for 30 cm soil layer* (rounded)
--- | --- | ---
Very light | 1533 | 4.6
Light | 1500 | 4.5
Medium | 1433 | 4.3
Heavy | 1300 | 3.9

* kg N 30cm = mg N kg\(^{-1}\) soil x W

Table 2. Soil density depending on soil textural classes

The tables 3 – 5 shows general statistics for the central tendency and the scatter of the data, in the form of percentiles for amounts of N\(_{\text{min}}\) and amounts of NO\(_3\) - N. Nitrate nitrogen is the form mostly preferred by plants and simultaneously very prone to leaching to the ground and open waters. Three soil layers, or rather profiles 0-30 cm, 0-60 cm and 0-90 cm have been distinguished. Fertilizer recommendations are usually based on the mineral nitrogen amount in these profiles with the preference for 0-60 cm and/or 0-90 cm profiles. The most interesting is the soil profile 0-90 cm which is explored by the roots of common crops. The difference in the amounts of nitrates in this profile between autumn and spring periods of soil sampling was further considered as nitrogen losses to the underground water. In the soil profile 0 - 90 cm (table 5) the median quantity of N\(_{\text{min}}\) amounted to 65 – 95 kg N ha\(^{-1}\) in spring and 79-96 kg N ha\(^{-1}\) in autumn. The quantity of NO\(_3\) - N ranged from 35 – 69 kg N ha\(^{-1}\) in spring and 52 -72 kg N ha\(^{-1}\) in autumn. The amount of nitrates and total mineral nitrogen increased from the very light soils towards heavy ones. The difference between the N\(_{\text{min}}\) and NO\(_3\) -N amounts in spring and autumn periods of soil sampling diminished in the same direction.

| Characteristics | Spring | Autumn |
| --- | --- | --- |
| | Soil texture | Soil texture | Soil texture |
| Number of samples | 10784 | 19585 | 8718 | 8710 |
| Median | 29,0 (14,7) | 33,3 (19,8) | 34,8 (22,9) | 35,1 (25,3) | 39,1 (26,2) | 44,5 (32,4) | 45,0 (33,5) | 43,7 (33,5) |
| 20% - percentile | 18,8 (7,36) | 22,0 (10,3) | 22,5 (12,3) | 22,6 (14,0) | 23,5 (12,4) | 27,4 (16,3) | 26,8 (17,0) | 25,7 (17,2) |
| 40% - percentile | 25,3 (11,9) | 29,7 (16,2) | 30,6 (19,1) | 30,4 (21,4) | 34,0 (21,1) | 38,7 (26,5) | 38,6 (27,6) | 37,0 (27,1) |
| 60% - percentile | 33,1 (17,9) | 37,8 (23,8) | 40,3 (27,2) | 40,2 (29,6) | 45,1 (31,7) | 51,7 (38,7) | 52,7 (40,8) | 50,3 (40,6) |
| 80% - percentile | 45,5 (28,0) | 52,2 (35,5) | 55,6 (39,9) | 55,8 (42,5) | 63,9 (48,7) | 72,4 (58,0) | 74,8 (59,9) | 72,9 (62,0) |
| 100% - percentile | 105 (74,0) | 108 (79,2) | 112 (82,4) | 111 (83,5) | 143 (119) | 145 (126) | 146 (126) | 145 (128) |

Table 3. Statistical characteristics of N\(_{\text{min}}\) and N-NO\(_3\) (in parenthesis) amounts in the soil profile 0-30 cm for soil textural groups and sampling date (kg N· ha\(^{-1}\))
Characteristics | Spring | Autumn |
|----------------|--------|--------|
| Soil texture    | Very light | Light | Medium | Heavy | Very light | Light | Medium | Heavy |
| **Median**      | 47,8 (25,3) | 58,5 (36,6) | 64,8 (44,3) | 67,1 (19,5) | 62,1 (41,4) | 71,1 (51,3) | 74,3 (54,8) | 73,3 (56,9) |
| **20% - percentile** | 30,3 (12,4) | 37,8 (18,9) | 41,6 (23,8) | 42,9 (26,3) | 38,2 (20,2) | 43,7 (27,0) | 44,7 (28,0) | 44,1 (29,6) |
| **40% - percentile** | 41,4 (20,2) | 51,3 (30,2) | 56,6 (36,9) | 59,0 (41,7) | 53,8 (34,0) | 61,4 (42,4) | 64,1 (45,3) | 63,2 (47,6) |
| **60% - percentile** | 55,2 (30,8) | 67,0 (44,1) | 73,9 (52,2) | 76,8 (58,9) | 71,7 (50,1) | 81,9 (61,5) | 86,5 (65,3) | 85,6 (68,2) |
| **80% - percentile** | 77,7 (49,2) | 93,7 (67,7) | 103 (77,5) | 106 (84,3) | 102 (76,1) | 116 (92,2) | 122 (98,2) | 122 (104) |
| **99% - percentile** | 187 (139) | 196 (157) | 202 (167) | 203 (171) | 235 (208) | 247 (218) | 248 (221) | 247 (223) |

Table 4. Statistical characteristics of $N_{\text{min}}$ and $N$-$\text{NO}_3$ (in parenthesis) amounts in the soil profile 0-60 cm for soil textural groups and sampling date (kg N· ha$^{-1}$)

Numerous factors, apart from the soil texture, influenced the amount of mineral and nitrate nitrogen in soil and differences between the autumn and spring period of soil sampling. In spring, the quantity of nitrogen is affected mainly by crop grown in the previous year, while in autumn by crops grown in this particular year (Table 6). The preceding and actually grown crops have been classified by means of cluster analysis into three groups differing in

| Characteristics | Spring | Autumn |
|----------------|--------|--------|
| Soil texture    | Very light | Light | Medium | Heavy | Very light | Light | Medium | Heavy |
| **Number of samples** | 10924 | 19902 | 8844 | 8024 | 10913 | 19829 | 8867 | 8068 |
| **Median**      | 65,3 (35,3) | 81,4 (52,5) | 90,9 (62,2) | 94,8 (69,4) | 79,3 (52,4) | 89,7 (63,9) | 95,4 (68,0) | 96,3 (72,5) |
| **20% - percentile** | 40,8 (17,0) | 51,3 (26,5) | 57,7 (33,1) | 59,7 (36,7) | 48,8 (26,2) | 55,1 (33,3) | 57,7 (35,5) | 57,3 (37,4) |
| **40% - percentile** | 56,6 (28,4) | 70,7 (42,7) | 79,4 (51,9) | 82,3 (57,7) | 69,0 (43,2) | 77,5 (52,8) | 82,4 (56,5) | 82,7 (60,1) |
| **60% - percentile** | 75,8 (43,7) | 93,6 (62,9) | 104 (73,9) | 109 (82,0) | 92,0 (63,0) | 104 (76,2) | 110 (81,8) | 111 (87,3) |
| **80% - percentile** | 107 (69,4) | 131 (96,3) | 145 (108) | 150 (119) | 132 (95,6) | 148 (115) | 159 (124) | 157 (131) |
| **99% - percentile** | 261 (196) | 283 (223) | 292 (234) | 298 (236) | 307 (253) | 32 (267) | 324 (271) | 324 (273) |

Table 5. Statistical characteristics of $N_{\text{min}}$ and $N$-$\text{NO}_3$ (in parenthesis) amounts in the soil profile 0-90 cm for soil textural groups and sampling date (kg N· ha$^{-1}$)
the amount of $N_{\text{min}}$ and $\text{NO}_3^-$ left in the soil. Cluster of crops reflects not only the type of particular crop but the agro technical measures for this crop as well, influencing the amount of mineral nitrogen in the soil. Sugar beet, potato and sometimes rape and maize are grown on farmyard manure. Leguminous crops assimilate nitrogen from the atmosphere and for intensive cereals and rape, high doses of mineral nitrogen are being commonly applied. Another factor influencing the amount of mineral and nitrate nitrogen in the spring period and the difference of these amounts between spring and autumn period is the winter precipitation. This factor will be discussed in the following part of the paper.

| Cluster | Soil layer | 0-30 cm | 0-60 cm | 0-90 cm |
|---------|------------|---------|---------|---------|
|         | $N_{\text{min}}$ | $\text{NO}_3^-$-N | $N_{\text{min}}$ | $\text{NO}_3^-$-N | $N_{\text{min}}$ | $\text{NO}_3^-$-N |
| I       | Spring     | 35,7    | 22,7    | 63,8    | 42,2    | 87,1    | 59,5    |
|         | Autumn     | 46,3    | 34,7    | 76,7    | 57,4    | 99,4    | 72,7    |
| II      | Spring     | 31,3    | 17,7    | 50,0    | 28,0    | 65,7    | 37,3    |
|         | Autumn     | 36,2    | 22,4    | 56,2    | 35,6    | 70,6    | 43,6    |
| III     | Spring     | 23,5    | 9,75    | 39,5    | 16,0    | 51,5    | 22,0    |
|         | Autumn     | 25,0    | 14,0    | 39,0    | 15,5    | 51,0    | 24,0    |

Table 6. Amounts of mineral and nitrate nitrogen in spring for clusters of preceding crops and in the autumn for crops grown in the particular year [kg N·ha$^{-1}$]

The largest amount of mineral nitrogen in soil has been revealed after intensive cereals (winter wheat and triticale), winter rape, row crops fertilized with manure (sugar beet, potato, vegetables and leguminous crops in a pure stand and with a mixture with grasses. The smallest quantity has been found after extensive cereals (rye, oats, cereal mixtures, non-leguminous fodder crops, grasses and on set aside land. Almost the same regularities appeared in the samples collected in autumn. The greatest differences in $N_{\text{min}}$ and $\text{NO}_3^-$-N quantities between autumn and spring period of soil sampling appeared in the cluster I. The quantities of nitrogen after crops of cluster III between autumn and spring periods of soil sampling in soil layers 0-60 and 0-90 cm were practically the same.

4.3 Application of $N_{\text{min}}$ test for fertilizer recommendations

A very serious and still unsolved problem is how to include the results of $N_{\text{min}}$ or $\text{NO}_3^-$-N test into nitrogen fertilizer recommendations. Generally, two approaches can be considered: quantitative and qualitative. The most straightforward quantitative approach is to express the content of $N_{\text{min}}$ in kg·ha$^{-1}$ and to relate its amount to the amount of nitrogen from fertilizers. Based on this approach the simple model has been developed in Europe:
Mineral Nitrogen as a Universal Soil Test
to Predict Plant N Requirements and Ground Water Pollution – Case Study for Poland

$N_{fer} = N_{crop} - N_{min} \times RFV$, where: $N_{fer}$ - optimal rate of fertilizer nitrogen, $N_{crop}$ - crop nitrogen requirement, RFV- $N_{min}$ replacement value. As has been already pointed out Wehrman et al. (1986) assumed that RFV value is equal to 1, while in Polish investigations this value depends on crop as well as on soil and climatic conditions and changes in the range 0,6 - 1,1 (Fotyma et al., 2007). The lack of universality of RFV poses a serious drawback in quantitative application of the $N_{min}$ soils test and since late 80ties qualitative approach gains popularity. This particular approach to soil test of mineral nitrogen has been implemented in Germany (Muller & Gorlitz 1986, 2000) and lately in Poland (Fotyma, 2010, Rutkowska & Fotyma, 2009). The first step in qualitative approach is to calibrate the soil test. Calibration is commonly understood as establishing the test critical value or several classes corresponding to the expected efficiency of a given nutrient. The classical method is to calibrate the soil test against plant indices in the series of field experiments carried on the soil differing in the test values. This is a very cumbersome and expensive procedure practically not applied any further. In Poland $N_{min}$ soil test has been calibrated using the data from monitoring program providing representative data for different natural and agronomic conditions in the country. The five test classes for mineral and nitrate nitrogen correspond to the percentiles of these forms in soils of different texture (Table 7). Each following interval contains 20% of ordered observations and thus five classes of $N_{min}$ and NO$_3$-N were distinguished - very low, low, medium, high and very high nitrogen content. Five calibration classes have been chosen in order to comply with the numbers of availability classes for other nutrients, officially used in Poland.

| Soil texture | Form of nitrogen | Class of content (percentile interval) kg $N_{min}$·ha$^{-1}$ |
|--------------|-----------------|---------------------------------------------------|
|              |                 | Very low 0-20% | Low 20-40% | Medium 40-60% | High 60-80% | Very high 80-100% |
| Very light   | NO$_3$-N        | to 17          | 18-28      | 8-11          | 29-44       | over 70           |
|              | $N_{min}$       | to 41          | 42-57      | 58-76         | 77-107      | over 108          |
| Light        | NO$_3$-N        | to 26          | 27-43      | 44-63         | 64-96       | over 96           |
|              | $N_{min}$       | to 58          | 59-79      | 80-104        | 105-145     | over 132          |
| Medium       | NO$_3$-N        | to 33          | 36-52      | 53-74         | 75-108      | over 109          |
|              | $N_{min}$       | to 58          | 59-79      | 80-104        | 105-145     | over 146          |
| Heavy        | NO$_3$-N        | to 37          | 38-58      | 59-82         | 83-119      | over 120          |
|              | $N_{min}$       | to 60          | 61-82      | 83-109        | 110-150     | over 151          |

Table 7. Classes of the mineral nitrogen $N_{min}$ and nitrate nitrogen NO$_3$-N in spring in the soil profile 0-90 cm

Soil test for NO$_3$–N seems to be more suitable for fertilizer recommendations than $N_{min}$ test. This is because nitrates are directly available for plants. Total amount of $N_{min}$ includes also NH$_4$ – N form, but NH$_4^+$ cation is preferred only by some specific group of plants, and besides undergoes the sorption on the soil colloids. The calibration figures are given for the soil profile 0-90 cm. For technical reasons soil sampling is sometimes limited to the depth of 0-60 cm. However data obtained from the monitoring program showed the close correlation between the amounts of mineral nitrogen in the two soil layers 0-60 and 0-90 cm. Classes of $N_{min}$ quantity in spring corresponds in reverse order to the classes of crop nitrogen requirements. In the class of very low mineral nitrogen content, crop requirements are the highest and vice versa. In fertilizer recommendations if the content of $N_{min}$ or NO$_3$–N
N in the spring falls in “medium” class farmer is enhanced to stick to the standard N rate and its common splitting pattern. If the N$_{\text{min}}$ content proved to be “very low” or “low” then the standard 1st rate of nitrogen fertilizer should be increased and applied as early as possible. The reverse is recommended when mineral nitrogen content is “high” or “very high”. Usually for deep rooting and/or winter crops the content of N$_{\text{min}}$ in the soil profile 0 – 90 cm and for shallow rooting and/or spring sown crops the content of N$_{\text{min}}$ in the soil profile 0-60 cm is taken into consideration. Thus, this qualitative approach to mineral nitrogen soil test makes it at present rather as an auxiliary tool for nitrogen recommendations system. The calculation of standard nitrogen dose is still in foreground. This problem lies however outside the scope of this paper and is discussed elsewhere (Jadczyszyn, 2000, 2009).

4.4 Application of N$_{\text{min}}$ soil test for environment protection

Agriculture in Poland is a main source for the leaching of nitrates to groundwater and surface waters. It is estimated that in the Baltic catchment over 60% of nitrogen in the riverine outflow originates from the diffuse sources. The diffuse outflow, as well as point sources are considered the main sources of nitrogen discharged by the Vistula and Oder rivers, the two out of seven largest rivers feeding the Baltic Sea. Fertilizer recommendations alike the problem is how to include the mineral nitrogen soils test in predicting the potential threat for ground water by excess of nitrates. It is clear that main losses of nitrate to ground water took place in winter and early spring periods due to the outflow of excess of water. Therefore, for environment protection, the content and distribution of nitrate in the soil profile in autumn are of paramount importance. On the base of data gathered from the soil monitoring program carried on in Poland since 1997, the threat from nitrate excess has been qualitatively assessed. The five classes of nitrate content in the soil profiles 0-90 cm and 60-90 cm corresponding to its pentiles distribution were distinguished (Table 8).

| Soil texture | Depth cm | Class of nitrate content kg N-NO$_3$ ha$^{-1}$ |
|--------------|----------|---------------------------------|
|              |          | Very low | Low | Medium | High | Very high | Median |
| Very light   | 0-90     | ≤27      | 27-43 | 44-62 | 63-94 | ≥97       | 52     |
|              | 60-90    | ≤24      | 5-7  | 8-11  | 12-20 | ≥42       | 9      |
| Light        | 0-90     | ≤233     | 34-53 | 54-76 | 77-115 | ≥116     | 64     |
|              | 60-90    | ≤24      | 5-8  | 9-13  | 14-23 | ≥54       | 10     |
| Medium       | 0-90     | ≤237     | 38-59 | 60-85 | 85-131 | ≥125     | 71     |
|              | 60-90    | ≤25      | 6-9  | 10-15 | 16-27 | ≥60       | 12     |
| Heavy        | 0-90     | ≤240     | 41-61 | 62-88 | 89-134 | ≥132     | 74     |
|              | 60-90    | ≤26      | 7-10 | 11-17 | 18-30 | ≥62       | 13     |

Table 8. The classes of nitrate content in autumn depending on the depth in the soil profile

The low content of NO$_3$-N in the very light and light soils and the medium one in medium and heavy soils are proposed in Poland as the threshold ranges of soil threatening with excess of nitrogen. These limits are roughly 40 kg N-NO$_3$ ha$^{-1}$, and 60 kg N-NO$_3$ ha$^{-1}$ for the very light/ light and medium/ heavy soils, respectively. Similar limits were established in few European countries as well. In Belgium the limit is set at 90 kg N-NO$_3$ ha$^{-1}$ in the soil layer 0-90 cm, in Germany at 45 kg N-NO$_3$ ha$^{-1}$ in mineral soils and at 90 kg in organic soils. The validity of our approach was confirmed by comparing the amounts of nitrates in autumn and spring periods (Table 9). It results from the table 7 that by low content of nitrate
in the very light/light soils and medium one in the medium/heavy soils the losses of nitrates from the soil profile 0-90 cm in winter period are negligible.

| Class of NO₃–N in autumn | Soil texture | kg NO₃–N ha⁻¹ in 0-90 cm | Very light | Light | Medium | Heavy |
|--------------------------|-------------|------------------------|------------|-------|--------|-------|
| Very low                 | autumn      | 16                     | 22         | 24    | 24     |
|                          | spring      | 21                     | 33         | 40    | 44     |
|                          | difference  | +5                     | +11        | +16   | +20    |
| Low                      | autumn      | 34                     | 43         | 45    | 49     |
|                          | spring      | 31                     | 46         | 54    | 60     |
|                          | difference  | -3                     | +3         | +11   | +11    |
| Medium                   | autumn      | 52                     | 64         | 68    | 73     |
|                          | spring      | 36                     | 53         | 65    | 71     |
|                          | difference  | -16                    | -11        | -3    | +2     |
| High                     | autumn      | 76                     | 92         | 99    | 107    |
|                          | spring      | 43                     | 62         | 72    | 81     |
|                          | difference  | -33                    | -30        | -27   | -26    |
| Very high                | autumn      | 132                    | 156        | 166   | 172    |
|                          | spring      | 51                     | 72         | 84    | 92     |
|                          | difference  | -81                    | -72        | -82   | -79    |
| Average for the soil     | autumn      | 52                     | 64         | 68    | 74     |
|                          | spring      | 34                     | 51         | 61    | 69     |
|                          | difference  | -18                    | -13        | -7    | -5     |

Table 9. Reserves of nitrates in autumn and following spring depending on the nitrate classes in autumn

4.5 Simulated nitrates concentrations in ground water

As has been already mentioned, for environment protection the key point is concentration of nitrate in the drinking water, which in fact originates from ground water and not the content of nitrate in the bulk of soil. The EU Nitrates Directive has stated the limit in drinking water to 50 mg·dm⁻³ NO₃ or 11,3 mg·dm⁻³ NO₃ – N. However direct estimation of this concentration is laborious and difficult. The most prone to leaching processes are nitrate in the deeper soil layers being in contacts with ground water, particularly in the periods of water saturation to full soils water capacity. Soil saturation to full water capacity in the depth 0-30 cm and 30-60 cm occurs only in the early spring but the subsoil nearly through the whole vegetation period.

In the paper the indirect method for estimation the safe limit of nitrate content in the bulk of soil by comparison with calculated nitrate concentration in the soil water at the depth 0-30, 30-60 and 60-90 cm was proposed, using the following formulas (5) and (6):

\[
\text{Concentration ( mg N-NO}_3\text{ dm}^{-3}) = \text{content (mg N-NO}_3\text{ kg}^{-1}) \times R, \quad (5)
\]

\[
\text{and } R=1/(W/D), \quad (6)
\]

where: W – soil water content in dm³ dm⁻³ (v/v), D- soil bulk density in kg·dm⁻³

The soil water content W at this point depends on soil texture. Standard W values for soil saturation to full water capacity and D values for soil categories in Poland are given in table

www.intechopen.com
The simulated concentration of nitrates in the soil layer 0-30, 30-60 and 60-90 cm are presented in Table 11.

| Soil texture | Soil bulk density G·dm$^{-3}$ D | Soil water capacity $v/v$, dm$^3$·dm$^{-3}$ | Soil water capacity $v/w$, dm$^3$·kg$^{-1}$ | Conversion factor $R$ | Coefficient $W_z^{(2)}$ |
|--------------|---------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------|--------------------------|
| Very light   | 1,533                           | 0,125                                         | 0,082                                         | 12,40                 | 2,65                     |
| Light        | 1,500                           | 0,174                                         | 0,116                                         | 8,62                  | 1,91                     |
| Medium       | 1,433                           | 0,291                                         | 0,203                                         | 4,93                  | 1,14                     |
| Heavy        | 1,300                           | 0,433                                         | 0,331                                         | 3,02                  | 0,77                     |

$^{(1)}$ coefficient to recalculate the content of nitrates in bulk soil into nitrate concentration in soil solution
$^{(2)}$ coefficient to recalculate the quantity of nitrates in the soil layer of 30 cm into concentration of nitrates in soil water

Table 10. Soil parameters for recalculation the content of nitrate in the bulk of soil to its concentration in soil solution assuming soil saturation to full water capacity

| Soil texture | Soil layer 0-30 cm | Soil layer 0-30 cm | Soil layer 0-30 cm |
|--------------|--------------------|--------------------|--------------------|
|              | autumn             | spring             | autumn             | spring             | autumn             | spring             |
| Very light   | 66,5               | 37,0               | 33,3               | 28,2               | 22,2               | 20,9               |
| Light        | 59,6               | 36,3               | 29,4               | 28,5               | 21,6               | 27,6               |
| Medium       | 37,9               | 26,1               | 19,7               | 19,2               | 11,3               | 18,8               |
| Heavy        | 25,4               | 19,0               | 13,9               | 15,4               | 8,2                | 10,9               |
| Average      | 48,2               | 30,5               | 23,4               | 22,2               | 13,8               | 16,3               |

Table 11. Simulated concentration of nitrates in the soil layer 0-30, 30-60 and 60-90 cm under assumption that the soil is saturated to full water capacity

The quantity of nitrates decreased from very light to heavy soils, which results in differences in their soil water capacity. Concentrations $\text{NO}_3^-$ N both in autumn and spring period diminish down the soil profile, independently of the soil texture. Except the heavy soils, the concentration of nitrates in the upper soil layer is strongly on behalf the autumn period in the intermediate soil layer still on behalf of autumn and in subsoil on behalf of spring period with except of the light soil. As a consequence of that, the downward movement of nitrates in the winter period with the water soaking into the soil profile occurs. Besides, the data in Table 13 indicate, that part of nitrates translocated from the upper soil layers is retained by the subsoil, particularly in medium and heavy soils. However, the remaining part is leached in soil profile below the rooting zone and potentially dispersed to the ground water.

In the monitoring program, soil samples to the depth 0-90 cm have been collected thus the concentration of nitrates below 90 cm can be simulated only. It has been assumed that the total quantity of lost $\text{NO}_3^-$ N during the winter period can be found in the depth of 90-120 cm and that the soil texture on this depth is the same as in subsoil. Hence, the quantity of nitrates expressed in kg N·ha$^{-1}$ removed to the soil layer 90-120 cm can be recalculate into nitrates concentration expressed in mg $\text{NO}_3^-$ N mg dm$^3$ in soil water using the coefficient $W_z$ (Table 10). The value of $W_z$ coefficient decreases from very light towards heavy soils as a result decreasing in the water capacity. For example, if the value of $W_z$ is 2,67, it means (Table 12) that 1 kilogram $\text{NO}_3^-$ N·ha$^{-1}$ leached to the depth of 90-120 cm in very light soil increases nitrates concentration in soil water by 2,65 mg $\text{NO}_3^-$ N·mg·dm$^{-3}$. The value of $W_z$
makes possible to assess the accessible amount of nitrogen leached to the soil (90-120 cm) - 4 kg NO$_3^-$ N mg·dm$^3$ for very light soil, 6 kg NO$_3^-$ N·mg dm$^3$ for light soil, 10 kg NO$_3^-$ N mg·dm$^3$ for medium soil and 15 kg NO$_3^-$ N mg·dm$^3$ for heavy ones. Of course, ground water with an exception of shallow wells is not the drinking water. Therefore, the simulated concentrations of the nitrates give only approximate values.

The differences between the autumn and the following spring in the quantity of nitrates can be treated as nitrogen losses to ground water. Of course, it is only a simplification, because part of the nitrates might be denitrified during the autumn – winter period, nevertheless, in the paper, the terms difference and losses would be used intermittently. In autumn, the losses in the medium class over winter period from medium and heavy soils are negligible and on light soils tolerable. Only very light, coarse - textured soils reveals a dangerous for nitrate leaching to the ground water. From the data presented it can be concluded, that the downward placement of nitrates below the depth 90 cm over the winter period depends on several factors among which soil texture and reserves of nitrates in autumn are the most important. The less influencing ones are intensity of crop production and the sum of rainfall from November to March. All the factors were aggregated at the administrative levels (NUTS – 2) of voivodship (Table 12) and included into cluster analysis. The results have been presented in the following subsection.

5. Discussion

The main achievement of this work was to establish the normative for $N_{min}$ content on the base of a soil monitoring program carried on in Poland since 1997. The normative concerning spring period of soil sampling can be used for fertilizer recommendations, and that concerning autumn period of soil sampling for environment protection. The official fertilizer recommendation system covers the whole territory of the country and is focused on individual farms. As it has been already mentioned $N_{min}$ soil test is, at present, an auxiliary tool superimposed on the standard nitrogen doses resulting from balance approach. Due to a very large number of farms in Poland, 1,5 millions altogether including about 0,3 millions of market oriented ones performing the $N_{min}$ soil tests for each field in each farm is out of a question. Therefore, the results of monitoring program in its spring part, which are made available for general agricultural community are treated as reference points for similar farming conditions (Jadczyszyn, 2009).

The normative concerning autumn period of soil sampling as well as a difference in mineral nitrogen content between spring and autumn periods of soil sampling are used for delineating the areas threatened by surplus of nitrogen from agriculture. Such approach is presented on the NUTS-2 scale, i.e. for administrative units the highest order, called provinces or voivodships. The whole territory of the country is divided into 16 provinces, which are further divided into 314 counties (Figure 1). This division is based rather on historical and socio-economical and not on natural grounds. However, most of the statistical Kopiński, 2006; Kuś et al., 2006). For this reason, as well as for full transparency, the problem of nitrogen surplus from agriculture is presented for administrative level NUTS – 2. Discussing this problem not only the results of the soil monitoring program for mineral data concerning agriculture are available on NUTS-2 scale only and this level is considered in most of the publications dealing with regionalization of agricultural policy (Krasowicz & nitrogen but other relevant factors have been taken into consideration. These factors are listed in Table 14 and some of them will be discussed briefly.
| Voivodship            | Winter rainfall (1) | Soil texture (2) | Cropping system intensity (3) | N balance difference kg N·ha⁻¹ (4) | Nitrates content in autumn kg N·ha⁻¹ (5) | Nitrate loss kg N·ha⁻¹ (6) |
|-----------------------|---------------------|------------------|-----------------------------|-----------------------------------|------------------------------------------|-----------------------------|
| Dolnośląskie         | 147                 | 22,1             | 78,0                        | 86,3                              | 87                                       | 14                          |
| Kujawsko-pomorskie   | 178                 | 71,2             | 65,6                        | 85,3                              | 67                                       | 14                          |
| Lubelskie            | 171                 | 71,9             | 66,3                        | 75,5                              | 61                                       | -1                          |
| Lubuskie             | 191                 | 86,9             | 63,3                        | 63,0                              | 77                                       | 32                          |
| Łódzkie              | 220                 | 84,3             | 48,0                        | 62,9                              | 64                                       | 18                          |
| Małopolskie          | 201                 | 28,2             | 66,1                        | 57,6                              | 68                                       | 2                           |
| Mazowieckie          | 174                 | 88,6             | 50,2                        | 54,9                              | 51                                       | 7                           |
| Opolskie             | 207                 | 42,5             | 79,8                        | 50,5                              | 73                                       | 11                          |
| Podkarpackie         | 200                 | 23,1             | 72,1                        | 50,2                              | 65                                       | 4                           |
| Podlaskie            | 188                 | 83,8             | 39,0                        | 48,4                              | 45                                       | 9                           |
| Pomorskie            | 208                 | 66,3             | 61,9                        | 48,1                              | 50                                       | 11                          |
| Śląskie              | 257                 | 56,1             | 66,0                        | 45,3                              | 71                                       | 7                           |
| Świętokrzyskie       | 207                 | 64,5             | 67,6                        | 42,1                              | 67                                       | -3                          |
| Warmińsko-mazurskie  | 206                 | 57,2             | 60,4                        |                                    | 44                                       | 7                           |
| Wielkopolskie        | 186                 | 93,1             | 65,8                        | 28,7                              | 78                                       | 27                          |
| Zachodniopomorskie   | 229                 | 78,3             | 63,0                        |                                    | 22,4                                     | 65                          |
| Polska               | 187                 | 64,7             | 62,8                        | 11                                | 63                                       | 12                          |

1) sum of rainfall in winter period (January 1st – March 31st)
2) % of coarse textured soil (very light and light)
3) % of samples from fields under intensive cropping system (see table 6)
4) difference between N input and N output annually (kg N·ha⁻¹).
5) amount of autumn nitrate N in soil profile 0-90 cm in kg ha⁻¹
6) differences between nitrate N content in autumn (1997-2005) and spring in kg ha⁻¹ (1996-2006)

Table 12. The losses of nitrate in winter period and influencing factors for voivodships in Poland
**Winter rainfall.** Analysis of data from monitoring program reveals that the nitrate losses in the period between spring and autumn soil sampling were related to the sum of rainfall in the period November to March. In the very dry years with winter rainfall below 100 mm the losses of nitrate were negligible. In the wet years with winter rainfall over 250 mm the losses of nitrates reached over 15 kg NO\textsubscript{3}-N·ha\textsuperscript{-1}.

**Soil texture** influenced strongly the content and losses of nitrate, and this factor was included in \( N_{\text{min}} \) normative. Particularly prone to nitrate losses are very light and light soils which share is very differentiated among the provinces. It is necessary to stress again upon the prevalence of light, sandy soils in Poland that contributes significantly to the nitrate outflow from the country.

**Cropping system** in Poland is partly linked to natural farming conditions, i.e. soil quality and climate. However, intensive, high demanding crops from economical reasons are often grown on light soils, and poor soil conditions are compensated by higher doses of mineral fertilizers.

**Nitrogen balance** is calculated in Poland according to OECD rules as a soil surface balance (OECD, 1999). N balance was positive in whole Poland. The mean N surplus was 57 kg N·ha\textsuperscript{-1}. The greatest surplus has been found in Kujawsko-Pomorskie and Wielkopolskie provinces. These regions are featured by a very intensive animal production and high consumption of mineral fertilizers. The smallest one has been found in Małopolskie and Podkarpackie voivodships characterized by the extensive agricultural production.

Factors listed in table 14, influencing the threat from nitrogen surplus have been included into the cluster analysis performed by Ward’s method. The voivodships were grouped in three clusters presented in table 15 and on the Figure 2.

| Cluster | Voivodship | Factor 1 Winter rainfall | Factor 3 Soil texture | Factor 4 Cropping system intensity | Factor 5 Autumn nitrate value | Factor 6 Nitrogen surplus kg ha\textsuperscript{-1} | Factor 7 Nitrate loss |
|---------|------------|--------------------------|----------------------|-----------------------------------|-----------------------------|---------------------------------|---------------------|
| I       | KUJ, LUB, MAL, OPL, PDK, SWT | 187                      | 46,2                 | 70,8                              | 69,7                        | 63,9                            | 5,85                |
| II      | DLN, LUS, SLS, WLP, ZAP      | 215                      | 78,6                 | 64,5                              | 72,7                        | 39,9                            | 22,7                |
| III     | LOD, MAZ, PDL, POM, WAM,     | 199                      | 76,8                 | 51,9                              | 50,8                        | 50,9                            | 10,0                |

Table 13. Clusters of voivodships (see Table 12)

The largest losses of nitrates were recorded in Dolnośląskie (DLN), Lubuskie (LUS), Śląskie (SLS), Wielkopolskie (WLP), Zachodniopomorskie (ZAP). Most of the area of these voivodships fall in the river Oder and/or 10 small rivers discharging directly to the Baltic Sea catchments. In the remaining voivodships grouped in clusters, I and III nitrates losses were much lower and did not exceed 10 kg NO\textsubscript{3}– N·ha\textsuperscript{-1}. The reason for the low losses of nitrate nitrogen in voivodships in the cluster I is prevalence of good soils. In voivodships of cluster III, the low nitrate losses could be explained by low quantity of NO\textsubscript{3}– N in soil in autumn and the lowest share of intensive crops in crop rotation. Most of the areas of these voivodship are located in Vistula catchment. Thus, the potential losses of nitrates to the ground water are higher in North – Western part of Poland than in South – Eastern one.
The most effective way for delineating the area threatened by excess of nitrate in drinking water originating from agriculture would be the monitoring program of ground water quality. Such program has been indeed launched in 1997 together with the program of soil monitoring for mineral nitrogen (Igras, 2004). However, the monitoring sites for both programs were fixed separately. Besides, the number of sites of the ground water program was much lower than for $N_{\text{min}}$ program. Since 2007, both programs have been merged, and until now the preliminary results are available (Jadczyszyn et al., 2010). Therefore the only representative data concerning nitrate concentration in ground water are showed in the present paper. Nevertheless, these data are simulated and need validation by comparison with the “true” concentration of nitrate in the ground water from the same sampling point. For these simulated data, the cluster analyses has been performed in order to group the voivodship according to the expected concentration of nitrate in the ground water. The percent of sampling points where this concentration exceeds the limit set by Nitrate Directive (Table 14) was also taken into consideration. The simulated concentrations of nitrates in soil water widely differ among the voivodships. On the base of Table 14 it has been concluded that in five voivodships grouped in clusters III and IV the median of nitrate concentration is very high and only about 40% of soil samples is in accordance with the Nitrate Directive. The soils of remain 11 voivodships are in the range of the safe limit below 11.3 mg NO$_3$ – N·dm$^{-3}$ but still in quite numbers of samples concentration of nitrate exceed this limit. The problem of delineating areas in Poland threatened by excess on nitrate in ground water needs further investigations, particularly in smaller than NUTS-2 territorial scales.
Cluster | Voivodship in the cluster | Median value mg NO₃-N·dm⁻³ water | % samples <11,3 mg NO₃-N·dm⁻³ water | Localization of voivodship in the cathment* \\
--- | --- | --- | --- | --- \\
I | LUB, OPL, SWT | 0,2 | 60 | LUB, SWT – V OPL - O \\
II | DLN, MAL, MAZ, PDK, PDL, POM, SLS, WAM | 8,0 | 55 | MAL, PDK, MAZ, PDL, WAM – V POM – V/R SLS – V/O DLN - O \\
III | KUJ, LOD, ZAP | 25,2 | 40 | KUJ, LOD - V/O ZAP - O/R \\
IV | LUS, WLP | 46,8 | 35 | LUS, WLP - O \\

*V – Vistula, O – Oder, R - 10 rivers directly charged to the Baltic Sea

Table 14. Clusters of voivodships according to simulated concentration of nitrates in ground water

6. Conclusions
- In the paper the normative of mineral nitrogen content in arable soils in Poland are presented. These normative correspond to the percentile distribution of the values of NO₃-N and NH₄-N content in the country-wide monitoring programme.
- The five-classes normative (pentiles) are calculated for each of four soil textural classes separately. The method of recalculation the content of nitrate in bulk soil into its concentration in soil water (assuming soil saturation to full water capacity) is proposed.
- The method for simulating nitrate concentrations below the rooting zone was proposed.
- The regions of Poland with high risk of ground water pollution by downward placement of nitrate were designated.

7. References
Carter, J. N.; Jensen, M. E. & Bosma, S. M. (1974). Determining nitrogen fertilizers needs for sugarbeets from residual soil nitrate and mineralizable nitrogen. *Agronomy Journal*, Vol. 66, pp. 319 – 323
Enckevort van, P. L. A.; Schoot van der J. R. & ten Berge van. W. (2002). A review of potential indicators for nitrate loss from cropping and farming systems in the Netherlands. Wageningen, the Netherlands: Plant research International.
Fotyma, E. (1995). Przydatność glebowego testu N_{min} w nawożeniu zbóż ozimych. *Fragmenta Agronomica*, Vol. 3, pp. 59 – 78
Fotyma, E. (1996). Metoda N_{min} w doradztwie nawozowym. *Zeszyty Edukacyjne IMUZ*, Vol. 1, pp. 67 – 74
Fotyma, M. & Ślusarczyk, E. (1992). Optimal threshold values for agricultural soils. *Zalecenia Agrotechniczne IUNG*. Vol. 51, No. 1, pp. 41-60
Fotyma, M; Fotyma, E. & Filipiak, K. 2007. Zastosowanie modelu QUADMOD do interpretacji wyników doświadczeń z nawożeniem azotem i modelowania potrzeb nawozowych roślin. *Fragmenta Agronomica*, Vol. 1, pp. 41-48
Fotyma, M.; Kęsik, K. & Pietruch, Cz. (2010). Azot mineralny w glebach jako wskaźnik potrzeb nawozowych roślin i stanu czystości wód glebowo - gruntowych. *Nawozy i Naważenie – Fertilizers and Fertilization*, Vol. 38, pp. 5 – 83

Igras, J. (2004). Zawartość składników mineralnych w wodach drenarskich z użytków rolnych w Polsce. Monografie i Raporty Naukowe IUNG – PIB, Vol. 13, IUNG-PIB Puławy, ISBN 978-83-7562-2008-5

Jadczyszyn, T. (2009). The Polish fertilization recommendation system NawSalD. *Nawozy i Naważenie – Fertilizers and Fertilization*, Vol. 37, pp. 195 – 203

Jadczyszyn, T.; Kęsik, K. & Pietruch, Cz. (2010). Resortowy monitoring zawartości azotu mineralnego w glebach Polski w latach 2007-2009. *Nawozy i Naważenie – Fertilizers and Fertilization*, Vol. 38, pp. 84 – 110

Krasowicz, S. & Kopinski, J. (2006). Wpływ warunków przyrodniczych i organizacyjno - ekonomicznych na regionalne zróżnicowanie rolnictwa w Polsce. *Raporty PIB, IUNG – PIB Puławy*, Vol. 3, pp. 81-99, ISBN 83-89576-26-0

Kuś, J., Faber, A. & Madej, A. (2006). Przewidywane kierunki zmian w produkcji roślinnej w ujęciu regionalnym. *Pamiętnik Puławski*, Vol. 124, pp. 195 – 210

Muller, S. & Gorlits, H. (1986). The relationships between soil inorganic nitrogen levels and nitrogen fertilizer requirements. *Agricultural Ecosystems and Environment*. Vol. 17, pp. 192 – 211

Nommik, H. (1996). The residual effects of nitrogen fertilizers in relation to the quantities of mineral nitrogen recovered in the soil profile. *Acta Agriculturae Scandinavica*, Vol. 16, pp. 23-35

OECD (1999). National Soil Surface Nutrient Balances: explanatory notes to interpret the data sheets. OECD Secretariat Paris.

Rutkowska, A. & Fotyma, M. (2009). Calibration of soil test for mineral nitrogen in Poland. *Communications in Soil Science and Plant Analysis*, Vol. 40, No. 1-6, pp. 987 -998

Scharpf, H. C. & Wehrman, J. (1975). Die Bedeutung des Mineralstickstoffvorrates des Bodens zu Vegetationsbeginn für die Bemessung der N – Düngung zu Winterweizen. *Landwirtschaftlich Forschung* Vol. 32, pp. 110-114

Scharpf, H.C. (1977). Der Mineralstickstoffgehalt des Bodens als Masstab für den Stickstoffdüngerbedarf. Disertation. Hannover

Terelak, H., Krasowicz, S. & Stuczyński, T. (2000). Środowisko glebowe Polski i racjonalne użytkowanie rolniczej przestrzeni produkcyjnej. *Pamiętnik Puławski*, Vol. 120, No. 2, pp. 455-469

Van Cleemput, O. & Hoffman, G., Vermoesen, A. (Eds). (1996). Progress in nitrogen cycling. In: *Plant and Soil Science*, Vol. 68

Van Cleemput, O. ; Zapata, F. & Vanlauwe, B. 2008. Guidelines on Nitrogen Management in Agricultural Systems. Training Course Series No. 29. International Atomic Energy Agency, Vienna

Van der Paauw, F. (1963). Residual effect of nitrogen fertilizer on succeeding crops in a moderate marine climate. *Plant Soil*, Vol. 19, pp. 324-331

Vandendriessche, H. (1992). Nitrogen fertilization: Nitrogen fertilization on cropland in relation to the environment. *Landbouwtijdschrift*, Vol. 45, pp. 395 – 402

Verhagen, A. & Bouma, J. (1997). Defining threshold values for residual soil N levels *Geoderma*. Vol. 85,23, pp. 199-211
Our dependence on soil, and our curiosity about it, is leading to the investigation of changes within soil processes. Furthermore, the diversity and dynamics of soil are enabling new discoveries and insights, which help us to understand the variations in soil processes. Consequently, this permits us to take the necessary measures for soil protection, thus promoting soil health. This book aims to provide an up-to-date account of the current state of knowledge in recent practices and assessments in soil science. Moreover, it presents a comprehensive evaluation of the effect of residue/waste application on soil properties and, further, on the mechanism of plant adaptation and plant growth. Interesting examples of simulation using various models dealing with carbon sequestration, ecosystem respiration, and soil landscape, etc. are demonstrated. The book also includes chapters on the analysis of areal data and geostatistics using different assessment methods. More recent developments in analytical techniques used to obtain answers to the various physical mechanisms, chemical, and biological processes in soil are also present.

How to reference
In order to correctly reference this scholarly work, feel free to copy and paste the following:

Agnieszka Rutkowska and Mariusz Fotyma (2011). Mineral Nitrogen as a Universal Soil Test to Predict Plant N Requirements and Ground Water Pollution – Case Study for Poland, Principles, Application and Assessment in Soil Science, Dr. Burcu E. Ozkaraova Gungor (Ed.), ISBN: 978-953-307-740-6, InTech, Available from: http://www.intechopen.com/books/principles-application-and-assessment-in-soil-science/mineral-nitrogen-as-a-universal-soil-test-to-predict-plant-n-requirements-and-ground-water-pollution