

Ecosystem Health and Sustainable Agriculture

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On the Sustainability of Conventional, Organic and Integrated Farming Systems

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CASE STUDY Lithuania

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Concepts and Groups

Agriculture operates on the interface of two complex, hierarchically organised systems: the socio-economic system and the ecosystem (Hart, 1984; Lowrance et al., 1986; Conway, 1987; Ikerd, 1993; Giampietro, 1994a; Giampietro, 1994b; Wolf and Allen, 1995; Giampietro, 1997, Gomiero et al., 2006). Prior to discussing the sustainability of different farming systems, it is worth remembering the place and relations of key concepts such as agroecosystem and farming system, from the point of agroecological science. Implicit in agroecological research is the idea that by understanding these ecological relationships and processes, agroecosystems can be manipulated to improve production and to produce more sustainably, with fewer negative environmental or social

impacts and fewer external inputs (Altieri, 1995). As illustrated in Figure 5.1, the agroecosystem (agri-ecosystem) can be described as a system arising at the intersection of natural and social-agrarian components and maintaining its homogeneity while various natural and anthropogenic components within its boundaries are in mutual systemic relationships. The farming system is then considered to be a complex of measures and actions of an agrarian character affecting the ecosystem, and managing the regimes of agroecosystem. Both are coupled in a dynamic relationship: The farming system determines the regime and functional conditions of the agroecosystem, while the agroecosystem influences the farming system's structure, cultivation methods, techniques, etc.

Around the beginning of the 21st century, due to increased environmental concern in the world, many dif-

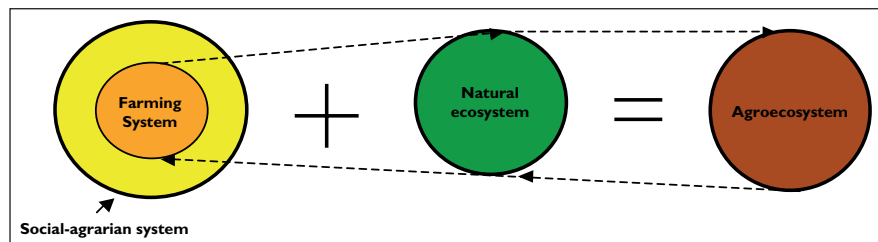


Figure 5.1. Agroecosystem as a result of the influence of the farming system, the component of social-agrarian system, on the natural ecosystem, with feedback. Adapted from Bučiene (2003).

ferent farming systems were introduced or remained after some changes in agricultural practices, although all these can be grouped into three main groups. These are: 1) Conventional (high input, intensive); 2) alternative (moderate or low input; organic, ecological, biological, biological-organic, etc); and 3) integrated (with a combination of elements from low and high input systems).

It is not easy to make a sustainability assessment of different farming systems due to the complexity of structural elements and their intricate relations. However, let us try to do this looking from the two main points: (i) nutrient flows and soil fertility status and (ii) nutrient leaching losses with drainage runoff.

Impact of Different Farming/Cropping Systems on Soil Fertility

Some Soil Properties Affected

Some soil properties, including mobile fractions of organic matter, available phosphorus (P) and potassium (K), microbial and enzyme activity, react quickly to changes in land use and management, whereas passive pools of soil organic matter, notably their organic nitrogen (N) and humus contents, are more stable (Bučienė et al., 2003). In many countries with various soil types, some essential plant nutrients in soil are declining in low-input systems as well as under continuous conventional cropping of monocultures (Scow et al., 1994; Liu et al., 1997; Askergaard, 1999; Løes and Øgaard, 1999; Krauss, 2000; Friedel and Gabel, 2001). In Central Norway, plant available phosphorus decreased in the soil of four of five organic farms (Askergaard, 1999), whereas research in Latvia and Russia (Zarina, 2000; Mishina, 1984) has shown that the crop rotation is among the crucial factors within farming systems, influencing the content of available P and K even in the reference treatments with zero input. The rotations with abundant crop residues are not only improving the physical properties of soil, but are also making more soil P (30-50%), Ca (14-19%) and Zn (13-17%) available to plants due to the larger amount of live roots penetrating deeper into the soil with retained plant residues (Mishina, 1984). However, investigations on organic farms on different

soil types in Lithuania have shown a more marked reduction in the contents of organic carbon, humus, available phosphorus and potassium in crop rotations involving legumes compared with crop rotations receiving organic fertiliser (Mažvila et al., 2003). Thus, it seems that crop rotations with abundant crop residues, particularly rich with legumes, still have to be studied more attentively in order to use all their advantages and avoid any disadvantages.

Importance of Soil Types

Soil type is also an important factor in this regard. The plant-available P_2O_5 -AL on Luvisols with a loamy texture increased in intensive cropping systems during two crop rotations, while it declined in the organic and integrated systems (Baltramaitytė, 2001) or did not decline during 4 years of further investigations of these cropping systems on plot level (Pupalienė and Stancevičius, 2003). However on gleic Planasols with medium loam texture at the organic farm of the Lithuanian Agricultural University, available P decreased by 16.5-37.1 mg kg⁻¹ and available K by 44.0-47.3 mg kg⁻¹ in the topsoil under the same crop rotation and management conditions as on Luvisols (Pekarskas, 2005).

Research on Albeluvisols in western Lithuania showed that available K did not change from the initial status for any crop management regime, but on Luvisols there was a significant increase in available P and K contents of topsoil under winter wheat, sugar beet, barley and ley in the rotation (Gužys, 1999). On the Luvisols in eastern Lithuania, the content of available P and K decreased in the organic management system, while it increased in the integrated and conventional systems growing winter wheat, maize, barley and ley in the rotation (Bundinienė, 2003). On the gleic Cambisols, one of the most fertile soil types in Lithuania, after 8 years of growing winter wheat, potatoes/rapeseed, barley with undersown ley, a statistically significant increase in content of available P and K was determined in both high input crop management systems (conventional and integrated) (Table 5.1).

The humus content was noticeably higher (by 0.72-0.99%) after four years of crop rotation in western Lithuania on Luvisols, Cambisols and particularly on Albeluvisols at any crop management regime (Gužys, Arlauskienė, 2001).

Definitions and Prerequisites

Table 5.1. Average topsoil nutrient status in the different crop management treatments in two rotations (I: 1995-1999 and II: 2001-2003) on Cambisols, Dotnuva, Lithuania.

| Treatments | Humus% | | N tot% | | P-AL mg kg ⁻¹ | | K-AL mg kg ⁻¹ | |
|------------|---------|---------|-----------|-----------|--------------------------|-------|--------------------------|---------|
| | I | II | I | II | I | II | I | II |
| CON | 2.8-2.7 | 2.7-2.7 | 0.16-0.17 | 0.17-0.16 | 51-61 | 68-74 | 64-81 | 102-95 |
| INT | 2.6-2.7 | 2.7-2.8 | 0.18-0.17 | 0.17-0.18 | 47-86** | 59-62 | 90-110** | 99-91 |
| ORG1 | 3.2-2.8 | 2.8-2.8 | 0.17-0.19 | 0.17-0.18 | 51-62 | 57-58 | 51-76 | 123-103 |
| ORG2 | 3.4-3.4 | - | 0.19-0.21 | - | 66-66 | - | 76-76 | - |
| REF | 3.4-3.0 | 2.9-3.0 | 0.15-0.18 | 0.18-0.20 | 65-77 | 67-80 | 60-78* | 102-85 |

* tact>t₀₅ ; ** tact>t₀₁ Note: The first figure shows the value at the beginning of rotation, the second that at the end. Explanation: CON – conventional with high rates of commercial fertilisers; INT – integrated with high rate (about 50 t ha⁻¹) of farmyard manure (FYM) as basic fertiliser supplemented with moderate rates of commercial fertilisers; ORG1 – with moderate rate of FYM (25-30 t ha⁻¹) and green manure; ORG2 – with moderate rate of compost of sewage sludge and straw (about 35 t ha⁻¹); REF- zero fertilisation or reference treatment (Bučienė et al., 2003; Bučienė et al., 2007).

Table 5.2. Mean percentage of water-stable aggregates (WSA) in the topsoil of the cropping systems on Cambisols in 1996 and 1999.

| Treatment ^a | WSA * | | | |
|------------------------|-----------|-------------|----------------------------|-------------|
| | > 1 mm | | > 0.25 mm (including >1mm) | |
| | 1996 | 1999 | 1996 | 1999 |
| CON | 8.2±0.02 | 10.2±1.55 | 50.7±0.35 | 43.6*±0.65 |
| INT | 7.5±0.04 | 15.2**±0.02 | 38.5±0.62 | 51.0**±0.42 |
| ORG1 | 12.0±0.24 | 17.6**±0.23 | 51.3±0.43 | 52.3±0.15 |
| ORG2 | 13.9±0.22 | 25.2*±1.48 | 57.3±0.72 | 64.2*±0.62 |
| REF | 11.3±0.17 | 15.8*±0.22 | 48.1±0.62 | 51.9*±0.07 |

*tact>t₀₅ ; ** tact>t₀₁

For treatment descriptions see Explanation below Table 5.1. (Bučienė et al., 2003).

On the gleic Planasols organic carbon decreased by 0.22-0.25% (Pekarskas, 2005), and a decrease was also recorded on Luvisols in all cropping system treatments (Baltramaitytė, 2001). However, on Cambisols organic carbon content did not change in the topsoil, but increased significantly in the subsoil horizon of different crop management regimes (Bučienė et al., 2003). The total nitrogen content did not change during both rotations in the topsoil of all treatments on Cambisols (see Table 5.1).

In eastern Lithuania on Luvisols with different topsoil texture, the organic matter content remained the same after a four-year rotation under the different crop management regimes (Bundinienė, 2003).

Implications for Soil's Physical Properties

Soil physical properties such as structural composition and content of water-stable aggregates have changed in

the treatments with different crop management systems on Cambisols (Table 5.2 and Figure 5.2).

The structure of these sandy loam Cambisols was typically good, with abundant aggregates 0.25-5 mm in diameter under the ORG1, INT and CON treatments (Figure 5.2 for explanation on treatments, see text under Table 5.1). The largest increase in aggregates in this size range was in the soil of the ORG2 treatment. The INT treatment showed little difference over the study period. The content of water-stable aggregates >1 mm by the end of the rotation had increased significantly in all treatments except CON (Table 5.2). The largest increase was in the INT system. The water-stable aggregates >0.25 mm increased most under the INT treatment, but they decreased substantially under the CON treatment, whereas there was no change in the ORG1 system. Thus, in general structural characteristics of the

soil under the INT and ORG2 treatments showed most improvement.

Implications for Humus Fractional Composition

Qualitative changes in humus fractional composition take place due to the crop rotation and cropping system. Research on the Luvisols (Baltramaitytė, 2001) has shown that after two crop rotations, the best humus composition was found in the integrated system and the worst in the conventional cropping system. On the Cambisols after the first rotation, the content of all humic acid fractions in the CON system decreased, and there was a trend towards an increase in the INT, ORG1 and REF treatments (Table 5.3). The HA1 fraction (the most mobile fraction of humic acids) remained fairly constant in all systems, while the HA2 fraction (bound with Ca) increased by

0.9% and by 0.5% in the INT and ORG1, respectively, but decreased by 0.5% in the CON treatment. The HA3 fraction (bound with clay particles) increased by 0.3% in the INT and REF systems and decreased by 0.4% in the CON system (Bučienė et al., 2003).

The sum of fulvic acids decreased over time in all treatments. By the end of the rotation there was a trend towards an increase in the mobile FA1 fraction in the INT and REF treatments. The FA2 (bound with Ca) and FA3 (bound with clay particles) fractions decreased in all the treatments, and the aggressive FA1a fraction remained the same. The HA/FA ratio changed, with the organic matter in general becoming richer in humic acids in all cropping systems. This in accordance with results obtained in Russia showing that when organic fertilisers had been applied for many years at high rates, the organic matter con-

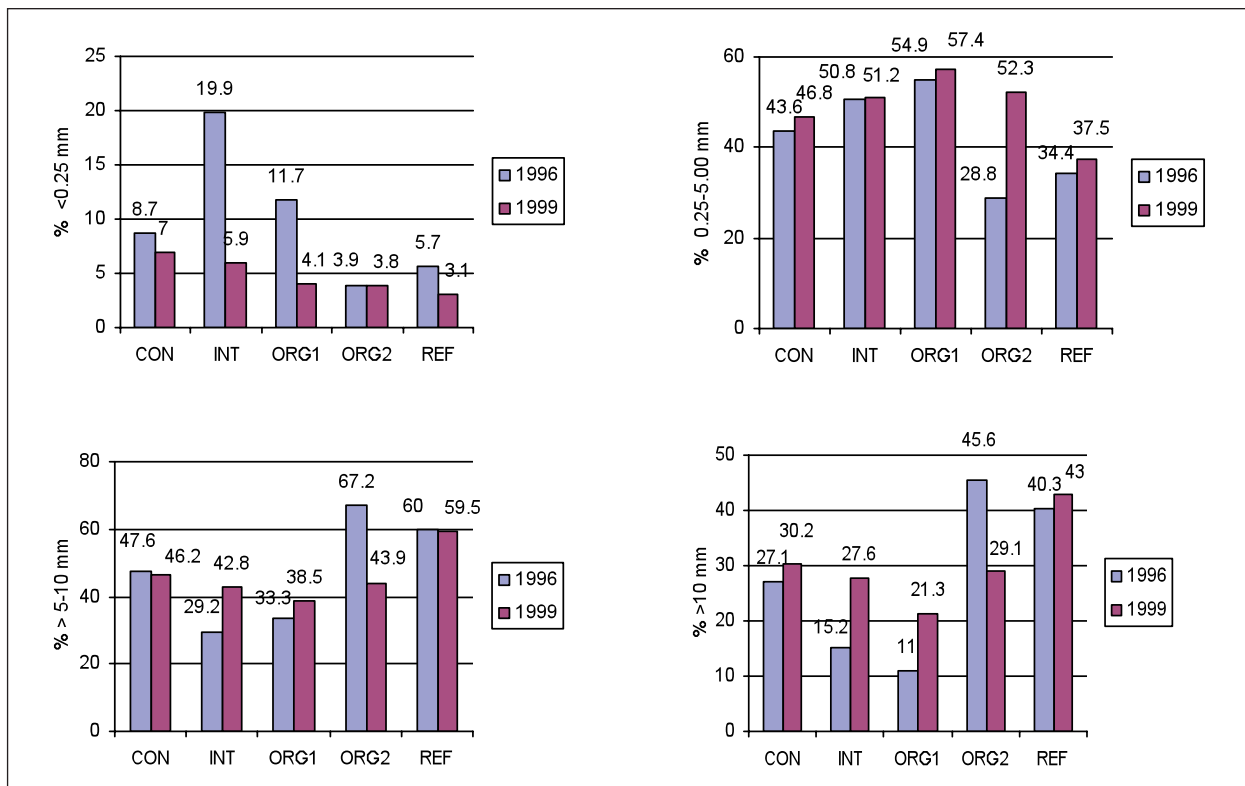


Figure 5.2. Distribution by size of topsoil aggregates in 1996 and 1999. For treatment descriptions see Explanation below Table 5.1. (Bučienė et al., 2003).

Definitions and Prerequisites

Table 5.3. Sum of fulvic acid (FA) and humic acid (HA) fractions and ratio (HA/FA) as a percentage of total soil in the different cropping systems on Cambisols, 1991-1999 (Bučiene et al., 2003).

| | CON | INT | ORG1 | ORG2 | REF |
|------------|------|------|------|------|------|
| ∑ HA 1991 | 0.54 | 0.30 | 0.54 | 0.56 | 0.41 |
| 1999 | 0.46 | 0.44 | 0.58 | 0.56 | 0.50 |
| ∑ FA 1991 | 0.67 | 0.52 | 0.76 | 0.76 | 0.62 |
| 1999 | 0.49 | 0.44 | 0.54 | 0.62 | 0.50 |
| HA/FA 1991 | 0.81 | 0.58 | 0.71 | 0.74 | 0.66 |
| 1999 | 0.94 | 1.00 | 1.07 | 0.90 | 1.00 |

For the treatment description see Explanation below the Table 5.1.

tent increased, as did the HA2 content, the most valuable fraction, while the total amount of fulvic acids decreased (Shatkhina and Khristenko, 1998).

Implications for Soil Microorganisms

The number and activity of different microorganisms in the soil varied little among the different cropping systems on Luvisols, Albeluvisols and Gleysols in Western Lithuania, but there was a tendency for higher numbers in the conventional system with higher inputs of fertilisers (Gužys and Arlauskienė, 2001). The same tendency was observed on Luvisols in eastern Lithuania (Bundinienė, 2003). Research on Cambisols in Central Lithuania showed that comparatively higher numbers of ammonifying microorganisms as well as spore-forming bacteria occurred in the CON system, while other groups of mi-

croorganisms were most numerous and the content of enzymes higher in the REF or ORG2 system (Table 5.4).

Summarising the results above, it can be stated that different low and high input crop management systems influence soil fertility elements (physical, chemical and microbiological) differently, depending on the initial soil nutrient status, soil type (horizons, texture, organic matter content, etc.), crop rotation and local climate specifics. In order to understand this impact, many site-specific conditions and factors have to be studied and analysed as background using integrated data processing and system analysis methods in each individual case.

Impact of Different Farming/Cropping Systems on Nutrient Leaching

There are different opinions concerning the impact of fertilisation and farming intensity on the amount of main nutrient leaching. Some researchers (Tyla et al., 1997; Ežerinskas, 1998; Bokhorst, 1989; Mažvila et al., 1992; Jankauskas, 1989) confirm that more intensive fertilisation enhances migration and leaching of ions such as Ca^{2+} , NO_3^- , K^+ , Cl^- , SO_4^{2-} , while others (Švedas, 1990; Švedas and Antanaitis, 2000) disagree about nitrogen. From data obtained with ^{15}N isotopes, it is evident that nitrogen in commercial fertilisers only contributes to a very small part of the leached amount of soil mineral nitrogen. However, almost all researchers agree that the leaching

Table 5.4. Impact of different cropping systems on the parameters of soil microbial activity on Cambisols by the end of rotation I, 1998-1999 (Bučiene et al., 2003).

| Parameters | CON | INT | ORG1 | ORG2 | REF | LSD05 |
|--|------|------|------|------|------|-------|
| Ammonifying microorganisms mln g^{-1} | 14.2 | 10.8 | 13.0 | 11.2 | 13.4 | 3.6 |
| Mineral N assimilating bacteria mln g^{-1} | 15.2 | 13.5 | 12.8 | 12.0 | 16.2 | 4.5 |
| Actinomycetes mln g^{-1} | 5.9 | 6.6 | 5.9 | 4.8 | 7.2 | 1.8 |
| Spore-forming bacteria ths g^{-1} | 460 | 397 | 306 | 375 | 318 | 155 |
| Micromycetes ths g^{-1} | 47.8 | 45.6 | 44.1 | 61.4 | 50.0 | 15.1 |
| Urease mg NH_3 g^{-1} 24 h^{-1} | 1.8 | 2.0 | 1.8 | 1.7 | 2.0 | 0.6 |
| Invertase mg glucose g^{-1} 48 h^{-1} | 69.1 | 65.8 | 76.0 | 80.0 | 74.0 | 16.9 |
| Nitrate reductase* mg NO_3 100 g^{-1} | 40.6 | 44.5 | 41.5 | 46.0 | 42.8 | 8.1 |

*in 1999. For treatment descriptions see Explanation below Table 5.1.

occurs when the nutrients are in surplus in the soil and mainly not during the vegetation period when they are taken up by plants. Thus crops are responsible for nutrient uptake and leaching amounts. Investigations on Cambisols on a watershed scale revealed that the largest quantities of nitrogen were leached from fields under row crops (22.4 kg ha⁻¹ year⁻¹), whereas leaching from spring and winter cereals was 18.9 and 16.5 kg ha⁻¹ year⁻¹, respectively, and the lowest N leaching was from fields under pastures (10.5 kg ha⁻¹ year⁻¹) (Kutra et al., 2006). This analysis also revealed that the fertilisation rate was not higher than the plant requirements (considering plant-available nutrient storage in the soil) and that minimal tillage systems are more effective in reducing leaching than changes in crop rotation. In other studies on Cambisols where different crop rotations were compared, the highest average DIN (dissolved inorganic nitrogen) concentration in drainage water and total leaching was determined in cereals and row crop rotations (Aksomaitienė et al., 2004), but there was no major impact of these crop rotations on phosphate concentration in drainage water and leaching.

Green manure crops or leys before winter cereal sowing will not always catch the available soil mineral nitrogen, as in wet autumns it might migrate to deeper horizons and leach with drainage runoff (Romanovskaja and Tripolskaja, 2003). In addition, FYM spread before winter wheat sowing on sandy loamy Haplic Dystric Cambisols adds to N_{min} leaching in the autumn (Tripolskaja and Romanovskaja, 2001).

Research with lysimeters on Luvisols has revealed that systematic fertilisation only with FYM or with FYM and mineral fertilisers can change soil acidity and nutrient content, not only in the ploughed horizon but also in the E1 and B horizons. Application of farmyard manure and mineral NPK fertilisers changes the intensity and character of phosphate migration, resulting in more intensive leaching of phosphates bound to organic compounds. Leaching of the soil fine dispersion fraction from the upper horizons and accumulation in an arenaceous quartz filter has been reported (Tripolskaja, 2004). According to Barrow (1979), the ions Na⁺, K⁺, NH₄⁺ desorb more P than Ca²⁺ and Mg²⁺. Since the first group of ions is more abundant in FYM, their occurrence in soil might provoke P desorption and increase P leaching (Marcinkonis and Karmaza, 2007).

Kirchmann and Bergström (2001) analysed the available literature and concluded that the average leaching of NO₃-N from organic farming systems over a crop rotation period was somewhat lower than in conventional agriculture, but the authors stressed that a proper comparison of leaching between two types of systems should take the yield into account.

Relatively few studies have been done on the losses of P by leaching in respect of different crop management practices (Breeuwsma et al., 1995; Sharpley et al., 1994; Bahman, 2003) though it is considered a problem in coarse-textured soils high in organic matter (Sharpley et al., 1994) and areas of intensive livestock farming (Breeuwsma et al., 1995; Bahman, 2003).

To determine the effects of low and high-input agriculture on nutrient leaching, several forms of arable land management were compared in a rotation experiment lasting 8 years on drainage plots on Cambisols and 4 years on Luvisols, Albeluvisols and Cambisols of western Lithuania (Bučienė et al., 2007; Gužys, 1999; Gužys, 2001). The aim of this experiment was to compare different crop management systems on a few soil types in respect of the major nutrients N, P and K and some micronutrient flows and balances, in order to reveal the most problematic points and to reduce the leaching losses. The results on the main nutrients are presented in Tables 3.5-6.

Mean N_{min}, P_{tot} and K losses during rotation I (1995-1999) with normal and extremely high discharge conditions by leaching in the CON treatment were significantly greater than in the REF treatment, and mean N_{min} and K losses were greater than in the ORG2 treatment (Table 5.5). Means P_{tot} leaching losses were similar in all treat-

Table 5.5. Leaching of major nutrients with drainage runoff (kg ha⁻¹ year⁻¹) from the different crop management treatments in two rotations on Cambisols, Dotnuva (Bučienė et al., 2007).

| | CON | INT | ORG1 | ORG2 | REF | LSD ₀₅ |
|------------------|-------|-------|-------|-------|-------|-------------------|
| 1995-1999 | | | | | | |
| Nmin | 53.4 | 47.7 | 40.1 | 17.9 | 33.2 | 22.3 |
| Ptot | 0.286 | 0.280 | 0.205 | 0.271 | 0.192 | 0.105 |
| K | 3.8 | 3.1 | 2.3 | 2.2 | 1.9 | 1.45 |
| 2001-2003 | | | | | | |
| Nmin | 13.4 | 8.8 | 14.4 | - | 11.8 | 14.0 |
| Ptot | 0.071 | 0.054 | 0.108 | - | 0.055 | 0.043 |
| K | 0.7 | 0.7 | 0.8 | - | 0.8 | 0.44 |

Definitions and Prerequisites

Table 5.6. Mean leaching of major nutrients with drainage runoff ($\text{kg ha}^{-1} \text{ year}^{-1}$) from the different crop management treatments on Albeluvisols, Luvisols and Gleysols, Vežaičiai, 1995-1998 (Gužys, 2001).

| | Albeluvisols | | Luvisols | | Gleysols |
|--------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| | ORG | CON | ORG | CON | CON |
| K^+ | 4.2 ± 0.6 | 4.7 ± 0.8 | 3.4 ± 0.4 | 2.2 ± 0.4 | 2.6 ± 0.4 |
| NO_3^- | 63.1 ± 16.6 | 100.7 ± 27.9 | 101.3 ± 13.5 | 82.4 ± 10.8 | 69.2 ± 22.2 |
| PO_4^{3-} | 0.108 ± 0.016 | 0.078 ± 0.004 | 0.162 ± 0.008 | 0.145 ± 0.014 | 0.155 ± 0.005 |

ments and thus there was no cropping system impact here. However during dry weather and under low discharge conditions (during rotation II, 2001-2003) there was no discernible difference in impact between high and low input systems on main nutrient leaching.

In western Lithuania, with the highest annual precipitation rate, leaching of the main nutrients was different on the various soil types under the same treatment and crop rotation (Table 5.6).

In general, the highest K leaching was determined on Albeluvisols, irrespective of the crop management system, and the highest PO_4 leaching on Luvisols and Gleysols. The lowest nitrate leaching was in the organic treatment on Albeluvisols, while on Luvisols it was higher in the organic treatment than in the conventional. On the Gleysols one treatment was studied, conventional cropping, where nitrogen leaching was also not among the highest values. Correlation-regression analysis of the experiment data revealed that nitrate leaching mostly depended on the organic matter/humus content of the topsoil (equation 1):

$$y = 483.2 + 239.31x_1 - 32.608x_1^2 \quad (1)$$

where y is nitrate content in kg ha^{-1} per year leached with drainage runoff and x_1 is humus content of topsoil in% (Gužys, 2001).

These results showed that differences in nutrient leaching were not always apparent in the crop management treatments studied, and therefore an attempt was made to search for factors other than crop management that affected nutrient leaching. Studies under Swedish conditions (Bergström and Johnsson, 1988; Larsson and Johnsson, 2003) revealed that soil textural class and organic matter content, crops and climate conditions are among the crucial factors influencing N leaching. Another study, conducted in Dotnuva experimental site with regression-cor-

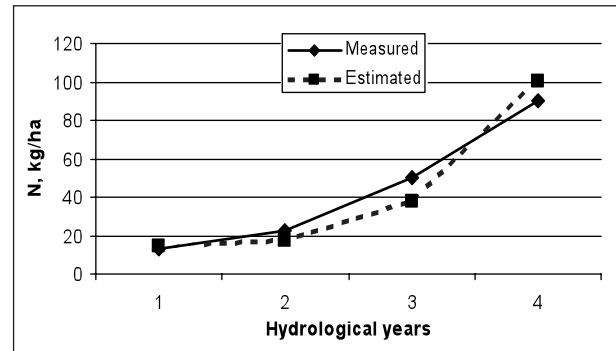


Figure 5.3. Comparison of measured annual leaching of mineral N and that calculated by equation (2) with drainage runoff during different hydrological years with low (1,2) normal (3) and high (4) discharge (Bučienė et al., 2007).

relation analysis (Švedas and Antanaitis, 2000; Bučienė et al., 2003) showed that the leached mineral nitrogen was a function of soil humus content, total nitrogen content, drainage discharge and amounts of active ingredients in mineral and organic fertilisers. Correlation-regression analysis of data obtained in this management study showed that nitrogen leaching mostly depended on crop characteristics (undisturbed permanent pasture or field crops established on arable land), drainage runoff/discharge magnitude and soil organic matter/humus, and was less well related to the amount of fertiliser applied (see equation 2). The N mineral leaching values estimated by equation (2) are in good agreement with the measured values (Figure 5.3):

$$y = (6.50x_1 + 65.01x_2 + 51.3x_3 + 0.01072x_4 + 0.05002x_5 - 4.35) \cdot 0.01x_3 \quad (2)$$

where y is N_{\min} in $\text{kg ha}^{-1} \text{ year}^{-1}$ leached with drainage runoff; x_1 is humus content of topsoil,%; x_2 is soil N_{tot} content in topsoil,%; x_3 is yearly runoff, mm; x_4 is active

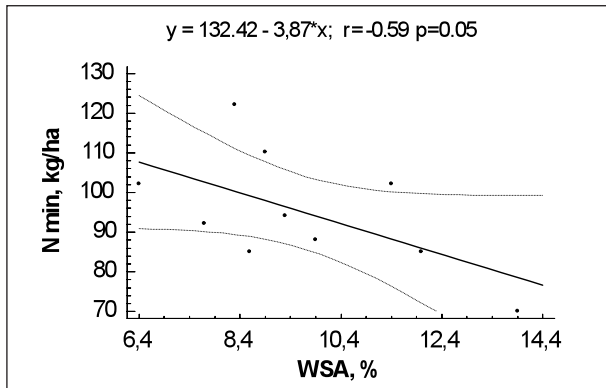


Figure 5.4. Correlation between N_{\min} leached with drainage runoff and content of water-stable aggregates > 1 mm in topsoil of Cambisols (Bučiene et al., 2007).

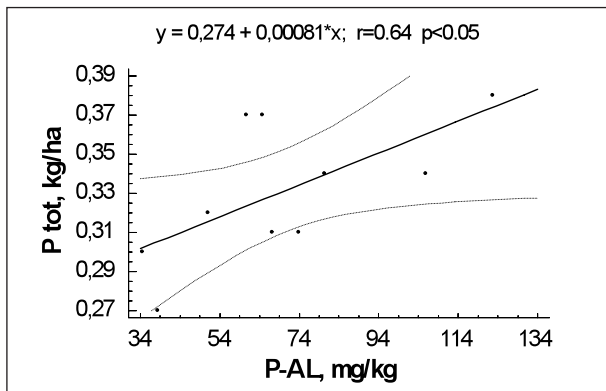


Figure 5.5. Correlation between P_{tot} leached with drainage runoff and available P_2O_5 -AL in the topsoil of Cambisols (Bučiene et al., 2007).

ingredients in N mineral fertilisers, $\text{kg ha}^{-1} \text{ year}^{-1}$ and x_5 is N in organic fertilisers, $\text{kg ha}^{-1} \text{ year}^{-1}$.

A close negative correlation was determined between annual N_{\min} leaching and the content of water-stable aggregates (WSA) in the topsoil of crop management systems on Cambisols in Dotnuva (Figure 5.4). Increasing the WSA content from 6.4 to 14% decreased mean annual leaching of N_{\min} from 108 to 76 kg ha^{-1} .

Leaching of P_{tot} in this experiment was positively correlated to the amount of available P_2O_5 -AL in the topsoil (Figure 5.5).

With an increase in available P_2O_5 -AL from 79 to 279 mg kg^{-1} leaching increased by almost 0.100 $\text{kg P}_{\text{tot}} \text{ ha}^{-1}$. This corresponds to other findings (Raupp, 1995; Indiat

and Sequi, 2004; Daniel et al., 1994; Sharpley et al., 1994) that P leaching is potentially higher with enrichment of soil with phosphorus.

Soil type and particularly the textural composition and organic matter content are other important factors that have to be considered when the impact of different cropping or farming systems on nutrient leaching are studied and compared. Long-term lysimeter studies with different types of soil in Lithuania (Tyla et al., 1997) have shown that particularly large amounts (75-90%) of the main nutrients leached from light-textured (loams, sandy loams), intensively cultivated carbonate soils.

Conclusions

1. Different low and high input crop management systems influence soil fertility elements (physical, chemical and microbiological) differently, depending on the initial soil nutrient status, soil type (horizons, texture, organic matter content, etc.), crop rotation and local climate specifics. Thus in order to understand this impact, many site-specific conditions and factors have to be studied and analysed as background using integrated data processing and system analysis methods in each individual case.
2. On Cambisols, organic cropping with moderate additions of compost (ORG2) caused the largest increase in aggregates in the 0.25-5 mm range and gave a high water-stable aggregate content in the topsoil. This may reduce N_{\min} leaching in this treatment during years with normal and high discharge. Of the low-input systems, this organic regime seemed the most sustainable.
3. Integrated cropping (INT) gave rise to the largest proportion of water-stable aggregates due to the high FYM rate. It also increased the available P and K in the topsoil and the total nitrogen and organic matter content in both topsoil and subsoil. The HA2 fraction increased most in this treatment, but much mineral nitrogen was leached in years with normal and high discharge.
4. Under conventional cropping (CON) there was a significant increase in the available K content of the topsoil.

Definitions and Prerequisites

The sum of all humic acid fractions including HA2 decreased. The microbial content and activity in this treatment were not significantly less than in the other treatments at the end of the rotation, but the loss of mineral nitrogen by leaching was the largest in years with normal and high discharge.

5. In the reference (REF) treatment the leaching of all nutrients was low, but not always significantly lowest.

6. Different cropping regimes did not influence the main nutrient leaching during dry conditions with low discharge on Cambisols.

7. Organic farming (ORG1) with moderate rates of FYM and green manure caused an increase in the most valuable HA2 fraction in the topsoil, but showed comparatively high N_{\min} leaching in the years with normal and high discharge.

8. A close negative correlation was determined between the annual amount of N_{\min} leached and the content of water-stable aggregates >1 mm in the topsoil of Cambisols.

9. Leaching of P_{tot} on Cambisols was positively correlated to the amount of available $P_2O_5\text{-AL}$ in the topsoil.

10. The regression equations (1) and (2) can be used for N leaching and balance calculations if there are data available on drainage discharge, the content of soil organic matter/humus, soil N_{tot} content, fertilisation rate and fertiliser chemical composition.

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