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The influence of soil characteristics on plant productivity and ecological stability

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The article is based on the abundant research material on both agricultural and forestry issues concerning the main characteristics of soil. The productivity of agricultural and forest crops is predetermined by soils, their granulometric texture, moisture regime, soil properties. Based on the applied FAO classification, the new approach was employed for investigating the impact of the main soil systematic units on the productivity of forests and agricultural crops. From the point of view of agricultural crops, Cambisols and Calcareous Luvisols are more productive (by approx. 30%) than Albeluvisols of the same granulometric composition (loamy sand, sandy loam, clay soils) and by approx. 15% than Haplic and Albic Luvisols, while the latter are by 15% more productive than Albeluvisols. Under the impact of various factors, a gradual degradation of soils is taking place in the country. It is caused by water, wind and chemical erosion, soil water-logging, strong acidification, compaction, contamination with heavy metals, pesticides, destruction of forest litter or its excessive accumulation, the high density of stands, establishment of pure spruce and pine stands, formation of ortzands in the soil, podzolization and gleyization processes. Fires are especially harmful to the soil.

From the ecological viewpoint, at present, the content of mobile phosphorus in most soils of the country causes no major threat of water contamination. However, the functioning large livestock farms produce high amounts of liquid manure and dung, the use of which for the fertilization of fields around the farms leads to a rapid increase of not only the content of phosphorus, but also of nitrogen, which may cause a serious threat to the ecological stability of the natural environment.

Causes of soil erosion and their consequences for agricultural plants and forests have been elucidated. A strong influence of human activities on soil characteristics by long-term fertilization, liming and drainage of land with water-logged soils, which sometimes lead to destabilization of the ecological balance, has been revealed. The obtained data could be successfully applied when tackling the questions of crop production in agriculture and forestry, as well as of a rational use of potential soil capacities.

Key words: plant productivity, soil characteristics, erosion, site types

INTRODUCTION

Among all known planets of the Universe, only on the Earth soils started developing approximately 2–2.5 billion years ago. Soil is the upper layer of the ground, formed under the influence of a range of soil-forming factors, such as climate, rocks, relief, vegetation and animals, human (anthropogenic) activities. All the factors are interrelated (Figure).

Soil is a very complex means of production in agriculture and forestry, which cannot be substituted by anything else; it is a unique natural phenomenon. Soil is a very thin (10–300 cm deep) and sensitive layer covering our planet. Soil formation and "maturation" requires several thousands of years. Its destruction in a certain area can last only several days or even several hours. The age of the oldest soils in the world reaches about 2 billion years; thus, prior to the appearance of soils, only bare rocks of different origin prevailed on the Earth. The surface of the Lithuanian territory, except for a small area in the southeastern part, was formed by sediments of the last Valday glacier left by the melting glacier 12–20 thousand years ago. The glaciers and their melting water resulted in a rather varied relief: hilly or wavy areas of the ground moraine, ridges of the rearmost moraine, fluvioglacial and limnoglacial plains. According to the genetic

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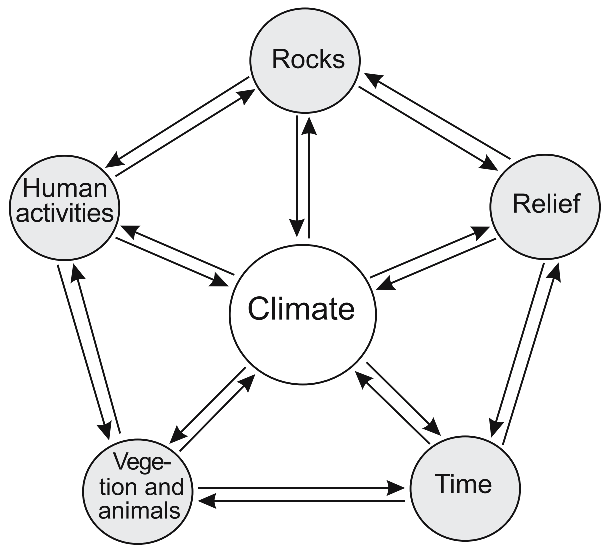

Figure. Soil-forming factors and their relationship (according to M. Vaičys)

type, 30% of the terrain in Lithuania are the ground structures of glaciers, 27% – peripheral ones, 23% – limnoglacial, 11% – fluvial, 7% – fluvioglacial, while the rest part are eolic, morainic, organogenic, sinkhole or erosion structures (Česnulevičius, 1999).

The structure of Lithuanian soils is varied and complex. It is predetermined by bioclimatic conditions, geomorphology, lithology, the granulometric and mineralogical composition of soil-forming rocks, their stratigraphy, calcareousness and pedofauna. Of no less importance for the formation of soils is the anthropogenic impact. Besides, Lithuanian soils differ by their absolute and relative age. The oldest soils are distributed in the southeastern part of the country, which was not covered by the last Valday glacier. Here, the moraine of the Dniepr ice sheet is deeply calcified, the soils are acidic. According to the depth of carbonates and carbonation, the moraine of the last Valday glacier is rather different. In the Atlantic period, with the prevailing warm and moist climate, the most intensive calcitization and leaching of clay particles (lessivage) was in progress. It continues up till now (Mažvila et al., 2008). A more or less intensive anthropogenic activity in Lithuania started approximately 5000 years ago with the development of agriculture. In the recent centuries, the anthropogenic impact has been intensified due to the development of industry, energetics, chemistry (especially fertilizers, pesticides), soil cultivation machinery, reclamation. A significant adverse effect on soil, forest, water and human health has had the long-range transfer of air pollutants. On hilly and more wavy areas, at different gradients of the ridges, due to anthropogenic impact and under the influence of water and wind erosion, not only the smallest particles are eroded in the upper and deeper soil layers, but also some nutrients are leached into the lower parts of the terrain, while in areas near rivers, streams and channels the leaching is direct (Mažvila et al., 2006).

The natural environment suffers from a considerable adverse effect of an unbalanced, sometimes jug-handled fertilization without accounting for the needs of plants, soil characteristics, from an untimely fertilization and improper storage of fertilizers.

MATERIALS AND METHODS

The paper presents generalized data of a long-term research carried out not only by the authors, but also by some research institutions in the soils of agricultural fields and forests. The object of studies were agro- and forest coenoses. Discussing soil genesis and its granulometric composition, generalized data presented by the State Land Survey Institute (SLSI) and the Lithuanian Forest Institute (LFI) were used; discussion of soil productivity of agricultural fields is based on data of the Agrochemical Research Centre (ARC) and other departments of the Lithuanian Institute of Agriculture (LIA), of agrochemical properties – on the ARC and of forest productivity – on the State Forest Survey Service (SFSS) data. The studies of forest soil characteristics involved data of the LFI.

Soil pH was ascertained in KCl extract by the colorimetric method, NNO_3 – by the calorimetric method using hydrazine sulfate and sulfanilamide, NNH_4 – by the colorimetric method using natrium phenolate and natrium hypochlorite. Mobile P_2O_5 and K_2O in field soils were studied by the Egner–Riehm–Doming (A–L) method, in forest soils – by Kirsanov's, humus in field soils – by dry burning at 800 °C with a Heareus analyser, in forest soils – by Tiurin's photocolorimetric method, total nitrogen – by Kjeldal's and hydrolyzable nitrogen – by Tiurin's and Kononova's method.

The yield of different agricultural crops (summer barley, wheat, winter rye, oats, sugar beetroots, potatoes, perennial grasses in the 1st and 2nd year of use, meadow grasses, mangel, winter and summer rape, buckwheat, t/ha) was recalculated into the general energy (GJ/t) by the method approved by LAI: the amount of total energy in winter wheat grains equalled 18.56, in winter rye 18.38, barley 18.48, oat 19.08, potato tubers 17.19, sugar beetroots 17.43, clover and timothy hay 18.00, cultural meadow hay 18.05, natural meadow hay 17.88, rape seeds 23.86, buckwheat grains 15.84, lupines 17.36, winter ryewheat 15.42 GJ/t.

The estimation of forest productivity and soil characteristics was based on the classification by Vaičys et al. (2006), compiled according to the degrees of soil fertility and humidity, where a site index and the mean timber increment are provided for each forest site type.

RESULTS AND DISCUSSION

Based on VAI data and according to the new classification by Buivydaitė et al. (2001), the largest areas are occupied by Luvisols (21%), Albeluvisols (20.4%) and Cambisols (16.8%), followed by Arenosols (11.9%). Histosols (9.5%), Gleysols (8.6%), the latter mostly in forests, Podzols (6.7%) being found only in forests, Fluvisols (3%), Planosols (1.6%), Regosols (0.4%). According to the granulometric composition of soil-forming rocks, sandy soils in the country comprise 17.7%, loamy sand 6.6%, light sandy loam 34.3%, light silty loam 1.5%, moderately heavy loam soils 19.3%, heavy loam 6.1%, clay 4.9% (Mažvila et al., 2006).

The productivity of field and forest plants is predetermined by soils, their granulometric composition, moisture regime, soil characteristics. The generalized data on the total energy of rotation fertilization trials in the control plots of most of agricultural fields in the country have shown that the most productive are Cambisols and calcareous Luvisols. These soils are more productive in the fields by about 30% than Albeluvisols of the same granulometric composition (sandy loam, clay loam, clay) and by 15% than common and podzolized Luvisols, while the latter are by about 15% more productive than Albeluvisols.

Soils in more hilly areas are affected by erosion. Slightly eroded soils of a heavier granulometric composition, if they are intensively cultivated and unprotected by grassy vegetation, due to water erosion every year lose not only a certain portion of smaller particles, but also nutrients. Crop production in them is by one third lower than in more productive Cambisols and calcareous Luvisols.

Moderately or heavily eroded soils on the inclinations of steeper ridges in hilly areas, if not afforested and still cultivated, are completely deprived of the earlier humus layer. Every year they lose about 20–100 t/ha of the smallest soil particles, a considerable amount of nutrients, the illuvial B horizon is eroded, their upper layer is humus-deprived and contains a very small amount of mineral nitrogen (Jankauskas, 1996, 2008). Thus, they produce only about 40–50% of the crop yield obtained in Cambisols and calcareous Luvisols (Mažvila et al., 2006).

A significant influence on the fertility of field soils is exerted by soil moisture regime. For instance, in undrained soils or in soils with improper drainage, crop production reaches only 65–70% as compared to drained areas, versus only 45–50% in Gleysols.

To produce a good and stable yield of different agricultural crops, the soil must contain sufficient amounts of nutrients. However, soils of our country usually lack them. Soils unfertilized for a series of years, at a depth of 0–60 cm contain only about 20–40 kg/ha of mineral nitrogen, mobile P_2O_5 and K_2O reaching 100 mg/kg.

Applying different rates of NPK fertilizers, it is possible to increase crop yield indices and to ensure favourable plant growth conditions. However, when applying fertilizers, it is necessary to take into account not only the needs of plants, but also soil characteristics, the content of different nutrients, climatic conditions. Applying nitrogen fertilizers, surplus accumulation of mineral nitrogen should be especially avoided in the soil after harvesting, because its excess under unfavourable climatic conditions is leached not only into deeper layers, but also into groundwater (Staugaitis, Mažvila et al., 2008). For instance, in Skemiai trial (Radviliškis region) in the spring of 2008, plots unfertilized for a series of years at a depth of 0–60 cm prior to barley sowing contained 33.8 kg ha^{-1} of mineral nitrogen versus 31.6 kg ha^{-1-} after harvesting. In unfertilized plots, in 2009 the content of mineral nitrogen was similar to that in the spring of 2008 (34.0 kg ha^{-1}). In plots fertilized with $N_{90}P_{90}K_{90}$ for many years, the content of mineral nitrogen at a depth of 0–60 cm was respectively 37.6, 54.3 and 43.8 kg ha^{-1}. This shows that fertilization of barley at a rate of 90 kg ha^{-1} has considerably increased the content of mineral nitrogen in autumn (up to 54.3 kg ha^{-1}) because the production of barley didn't require such an amount of nitrogen fertilizers, and its surplus in autumn accumulated in the soil. However, in the spring of 2009, although in winter the ground was frozen from the beginning of January to the end of March, precipitation water was leaching nitrates into deeper (especially into 60–90 cm deep) layers, and some of them were leached into groundwater. To avoid this in soils in which a higher content of mineral nitrogen remains after harvesting, it is purposeful to sow intermediate crops and to introduce their mass into the soil in spring.

The productivity of forest soils is assessed by the height of stands at maturity (m), mean timber increments (m^3 ha^{-1}) as well as by the site productivity indices (Table 1). Site types in this table are described according to systematic units and granulometric composition of soils.

Based on a research done by the State Forest Management Institute, the site index (the ratio of age and height) of stands growing on each forest site and their mean annual increment (m^3 ha^{-1}) were estimated. The data may be successfully applied in selecting the most productive tree species for different site types with regard to the genetic denominations of soils and their granulometric composition (Vaičys et al., 2006).

Circulation of different materials is taking place in the ground, seas and oceans. The major and the minor biological cycles are distinguished (Remezov, 1959). *The major geological cycle* took place prior to the appearance of life on the Earth, i. e. in abiotic conditions. *The minor biological cycle* started with the appearance of life on the Earth. Its characteristic feature is that different living organisms in a way extract nutrients from the geological cycle and accumulate them in the form of organic matter. The circulation between stand and soil is permanent, although it proceeds in a pulsating manner: during the vegetative period it is intensive, while in winter it slows down. The more complex the stands and the deeper their root system, the more varied and intensive the circulation. The intensity of biological cycle in forests partially may be judged from the litter. Its accumulation shows that the circulation of nutrients has slowed down. When the mass of droppings almost equals the mass of forest litter, the biological cycle and circulation of nutrients are very intensive; however, this statement is sometimes not suited for sparse pine stands with a low site index, producing less droppings. In ash, lime stands, the mineralization of forest litter is highly

Table 1. **Productivity of stands on the main forest site types**

Soil type	Granulometric composition	Forest site type	* Site index	* Mean increment $m^3 ha^{-1}$
Normal humidity (N)				
Regosols, Arenosols	s	Na	P-III,1	4.3
Arenosols, Podzols	s	Nb	P-II, 1; E-II, 7; B-I, 7	6.4
Cambisols, Luvisols, Planasols, Albeluvisols, Arenosols, Fluvisols	ps-m	Nc	E-II, 1; P-I, 3; B-Ia	6.7
Cambisols, Luvisols, Fluvisols	p-m	Nd	E-II, 2; B-Ia, 6; Ą-1,7; U-I, 3; Bt -I, 5	5.9
Cambisols	p-m	Nf	U-I; B-Ia, 5; E-II, 1	5.9
Temporarily overmoistured (gleyic) soils (L)				
Arenosols	s	La	P-III, 2; B-III, 7	3.3
Arenosols, Planosols, Podzols	s; s / s / p	Lb	P-I, 9; E-II, 5; B-I, 6	6.1
Cambisols, Luvisols, Planosols, Albeluvisols, Arenosols	ps-p1	Lc	E-II, 4; B-I, 1; P-I, 5	6.3
Cambisols, Luvisols, Fluvisols	ps-m	Ld	B –Ia, 9; E-11, 4; Bt-1, 6; U-1, 5; J-I, 3; Ą-I, 8	5.8
Cambisols, Luvisols	ps-p2-m	Lf	U – 1, 1; B-Ia, 7; E-II, 2; D – IA, 5	5.8
Permanently overmoistured (gley) soils (U)				
Gleysols	s	Ua	P-III, 9; B-III, 4; J-III, 7	3.5
Gleysols	s	Ub	P-II, 8; B-II, 5; E-III, 3	4.7
Gleysols	ps-p1	Uc	B-I, 9; J-I, 9; E-III, 0; Bt-II, 4	5.2
Gleysols	ps-m	Ud	J-I, 3; B-I, 5; E-II, 7	5.8
Gleysols	ps-m	Uf	J-Ia, 9; B-I, 1; U-I, 3; E-II, 2	5.9
Drained Histosols (Pn)				
Fibric Histosols	d / d; d / s-m	Pan	P-IV, 8; B-III, 9	3.3
Terri-Fibric Histosols	d / d; d / s-m	Pbn	P-III, 3; B-II, 4; J-II, 2	4.8
Mesotrophi-Pachiterric Histosols	d / d; d / s-m	Pcn	P-II, 0; E-III, 0; J-1, 9; P-II, 7	5.2
Eutrofhi- Pachiterric Histosols	d / d; d / s-m	Pdn	J-I, 3; B-I, 6; E-II, 8; U-I, 6	5.7
Undrained Histosols (P)				
Fibric Histosols	d / d; d / s-m	Pa	P-V, 5; B-IV, 3	2.7
Terri-Fibric Histosols	d / d; d / s-m	Pb	P-IV, 4; B-III, 1; E-III, 4	3.6
Mesotrophi-Pachiterric Histosols	d / d; d / s-m	Pc	B-II, 5; J-II, 2; E-III, 3; P-III, 5	4.6
Eutrofhi-Pachiterric Histosols	d / d; d / s-m	Pd	J-I, 4; B-I, 9; E-II, 9	5.8

* Data of 2003 by State Forest Survey Service.

Explicative signs of site types

Humidity degrees

N – normal humidity (dry) soils

L – temporarily overmoistured (gleyic) soils

U – permanently overmoistured (gley) soils

P^n – drained Histosols

P – undrained Histosols

Site fertility degrees

a – very infertile

b – infertile

c – fertile

d – very fertile

f – extremely fertile

Symbols (indices) of tree species

P – pine
B – birch
E – spruce
D – aspen
Ą – oak
J – black alder
U –ash
Bt – grey alder

intensive, and as soon as in the second part of the summer only twigs remain on the ground. Droppings in forests are usually accumulated closer to the stems of trees. The minor nutrient cycle is taking place in agricultural crops as well, only on a smaller scale and is less distinct.

The influence of forest and agricultural crops on soils. It depends on the species composition of crops and ecological conditions. Most researchers state that broadleaves exert a favourable effect on soil formation, while conifers have an adverse effect. The greatest negative influence on soils is exerted by dense spruce stands, the droppings of which form a rough and acid, slowly decomposing forest litter. The litter of pine stands is less agressive in respect of the soil. There is no unanimous opinion concerning larch, and some consider it to be a soil-improving species (Vaičys et al., 1966). Wittich (Wittich, 1961) points out that in larch stands, especially in denser ones, a rough, felt-type acid forest litter is formed. In this respect, larch can be rehabilitated, as its powerful root system is able to assimilate nutrients from deeper soil layers, and it enriches the upper soil layers with its droppings. In this respect, larch can be compared to oak which has a still deeper root system and bears leaves instead of needles. In our investigations, the most favourable effect on soil formation was shown by linden, ash, black alder, grey alder, maple, hazel. Less favourable properties among broadleaves are characteristic of birch and especially of aspen because its leaves in some cases form a slightly slower decomposing forest litter. Besides, the influence of forest trees on soil formation to a great extent depends on the characterisitcs of the soil itself, i. e. granulometric composition, the depth of carbonates, pH, humus content, composition of cations, hydrothermic regime.

Farming activities have a considerable influence on soil formation and soil characteristics. Applying different agrotechnical and reclamation measures, humans can severely change not only the character and direction of soil formation, but also soil characteristics, its fertility, cause water and wind erosion. There are various farming activities: soil cultivation, fertilization, liming, changing of stand species composition by cuttings, establishment of new plantations, trampling, use of pesticides. However, improper farming and neglect can lead to the degradation of soils.

Degradation of soils is caused by water, wind and chemical erosion, overwatering, heavy acidification, soil compaction, contamination with heavy metals, pesticides, destruction of pedofauna and forest litter, excessive density of stands, establishment of pure spruce and pine stands, formation of ortzands and ortsteins in the soil, podzolization and gleyzation processes, removal of forest litter or its too abundant accumulation on soil surface (*mor ectohumus*). An especially great damage to soils is caused by fires, which destroy the forest, its undergrowth, underbrush, scrubs, mosses and lichen, pedofauna. High fires severely destroy the crowns of trees, while low fires damage the aboveground parts. Low fires are especially harmful in peatlands where their extinguishing is highly burdened. The ecological balance after intensive fires is restored only after 40–50 years. Air pollution by harmful substances causes forest decline, contaminates soil and water. Air pollutants, irrespective of the country borders, travel for thousands of kilometres. The accident in Chernobyl has heavily polluted even the air in Lithuania by radioactive particles, contaminated its vegetation, soils, has affected the health of humans and animals.

Modern intensive farming is most often based on the use of different chemicals, such as mineral fertilizers, pesticides, defoliants, growth stimulators, etc. Frequent are the cases when farmers try to correct agrotechnical mistakes and negative soil properties by an unreasonable application of fertilizers and pesticides, thus contaminating soils, groundwater and plant production with their harmful components. By doing this for a series of years, they saturate the soil with the mentioned substances to the level when the soil itself is unable to resist the excessive load and becomes vulnerable in one or another way, or simply degrades. It is related to the worsening of physical, chemical and biological characteristics, loss of some mineral and organic compunds, and most importantly a decrease in fertility. This is most often manifested by a decrease in humus amount, the worsening soil structure, increased soil compaction, soil acidification, intensified erosion processes – runoff of the smallest soil particles and loss of nutrients. One of the most active forms of human interference is soil drainage in farmlands and open ditches in the forest (Vaičys, Oniūnas, 1992). A significant trace is left by liming and fertilization of soils. However, the heaviest damage to the soils of our country in hilly areas is caused by water, while in the soils of light granulometric composition – by wind erosion which not only reduces soil fertility, but also contaminates the natural environment and groundwater.

Seeking to protect the natural environment and especially water bodies against pollutants such as nitrogen and phosphorus compounds, to reduce soil erosion to the minimum, it is necessary, first of all in eroded areas, to select suitable crop rotations and to grow intermediate plants. Besides, to reduce erosion, anti-erosive soil cultivation should be applied (to leave unploughed stubble in autumn, apply strip farming, anti-erosive rotation, direct sowing into stubble, balanced fertilization, etc.).

To reduce the effect of wind erosion in agricultural areas and the subsequent contamination of water bodies, it is recommended to plant rows of trees and bushes in areas of Arenosols unprotected from prevailing winds, providing crop plants with a cover and ensuring wind protection, to leave stubbles and larger seedbeds over winter, to apply organic fertilizers and plant remains to mulch sandy soils, to minimize cultivation on sandy soils, while the cultivation and rolling procedures should comprise a single operation, to grow perennial or semi-perennial plants.

In the forest, soil is often degraded by hard ortzand layers. Ortzand is a new soil neologism. It is usually formed in the soils of light granulometric composition – sandy soils, less frequently in loamy sands, especially in places where groundwater is not very deep (1–1.5 m) and where intensive podzolization is in progress. Ortzands accumulate iron, aluminium, manganese, humus, colloidal particles. There are thick and hardened ortzands which the roots of trees fail to penetrate. Surface water usually accumulates on top of them, leading to gleyization, boggying up and soil degradation. Besides, when ortzand contains much aluminium, it becomes harmful to plants. Ortzands can be destroyed by deep ploughing, liming and fertilization. Turned out to the surface, due to atmospheric effects ortzands decompose over several months. In some places where the ortzand layer is neither very thick nor hard to provide a better water circulation, 70–100 cm deep drills are made, allowing surface water to reach deeper soil layers.

Soil acidification. Although after intensive and long-term liming (in 1965–1990 at 160–200 thous. ha annually) the area of relatively acid soils (pH_{KCl} 5.5 and less) in 1985–1993 decreased to 18.6%, highly acid (pH_{KCl} 4.5 and less) soils comprise up to 1.5%, averagely acid up to 9%, slightly acid 10.1%. However, since 1992–1996 when the volume of liming had been considerably reduced (to 5–40 thous. ha) and since 1997 was ceased completely, originally acid soils have been undergoing acidification and are gradually returning to their initial condition before liming. The most intensive acidification is characteristic of the West Lithuanian soils where the calcareous layer lies deeper (1.5–3 m) and has a more pronounced elluvial horizon than the rest soils of the country. The deeper layers of these soils prior to intensive liming were highly or averagely acid. According to data of 1995–2006 as compared to 1986–1990, the area of conditionally relatively acid soils in this zone has increased on an average by 8.7%, while in separate administrative regions it is considerably larger: in Plungė region 29.9%, Tauragė 13%, Šilalė 12.3%. This is of great concern to farmers because soils of a heavier granulometric composition (ps, p, p1-m) in the case of very acid soils as compared to those close neutral, produce only 66–74% of the total yield, in the case of average acid soils 74–86%, and in the case of slightly acid about 93%, as compared to soils with pH > 5.5. To prevent soil acidification before Al content has significantly augmented and while there are still sufficient contents of Ca and Mg, it is necessary to treat soils by applying maintenance liming. First of all, soils that have now acidified up to the level of pH 5.0 (although previously treated) should be limed at least at the rate of 2–4 t/ha.

Changes of forest soil pH over a certain period of time depend on soil genesis, granulometric composition, climatic conditions, stand species composition, on the influence of air pollution and human activity, AE horizon of podzolized sandy soil, its pH. Forest soil researchers have ascertained (Mažvila,Vaičys, 2006) that over 30 years (1965–1995) the AE horizon of podzolized sandy soil has acidified from pH_{KCl} 4.1 to pH_{KCl} 3.4, or by 0.7 pH, while in Cambisols ($\frac{S_1}{m}$) from pH_{KCl} 5.2 to pH_{KCl} 4.7, or by 0.5 pH, i. e. less fertile Arenosols have become more acid 7 times and more fertile Cambisols 5 times. The amount of pH in these soils in the future will depend on air pollution, the effect of acid rains, changes in stand species composition.

Based on long-term forest soil studies, pH_{KCl} indices for every 10 cm up to the depth of 90–100 cm have been determined for all mineral and organic forest sites (Tables 2, 3). Forest litter is usually less acidic than the upper, generally 0–10 and 10–20 cm deep, layers of mineral soil.

With increasing the trophicity of soils and forest sites, the pH index usually increases. However, there are cases when this relationship does not hold. For example, the pH of calcareous loose sandy soils, even in upper horizons, is neutral or even alkaline; however, such soils, due to poor physical properties (low moisture capacity), quite often are highly infertile. A closer positive relationship between pH and fertility as well as the content of nutrients is observed in Histosols, i. e. on boggy forest sites (Table 3). On boggy forest sites, Histosols after drainage acidify even to the depth of 90 cm because of a higher leaching of Histosols, decrease in base cations and a higher hydrolysing acidity (Vaičys, Oniūnas, 1992).

Phosphorus content of soils. Phosphorus is important for the growth and development of agricultural crops and woody vegetation. Contrary to trees which, having a well developed root system, take advantage of phosphorus present in deeper layers, agricultural crops require a sufficient amount of phosphorus to be available in the humus layer. Based on the studies in 1995–2006, soils with a very low content of phosphorus (<50 mg kg^{-1}) comprise 11.2%, with a low one 33.4%, average – 26.6%, high – 13.7%, high and very high – 15.1%. Best supplied with available hosphorus (P_2O_5) are soils of Central Lithuania. Here, soils with a low content of phosphorus comprise only 2.9%, while those with a high and very high content (>200 mg kg^{-1}) make almost one-fifth (18.6%) of the studied area. The situation is significantly worse in West Lithuania where soils with a very low content of phosphorus comprise 24.2%, low – 41.2%, moderate – 18.2%, while those containing suffiecient amounts of phosphorus make up only 16.4%

Table 2. **Mineral soil pH_{KCl} in different forest site types**

Sampling depth, cm	Forest site types														
	Na	Nb	Nc	Nd	Nf	La	Lb	Lc	Ld	Lf	Ua	Ub	Uc	Ud	Uf
O (Ao)	4.4	4.8	5.1	5.4	5.6	4.2	4.4	4.8	5.2	5.4	4.3	4.6	5.0	5.3	5.5
0–10	4.3	4.2	4.4	4.8	5.5	3.9	4.2	4.6	5.1	5.6	3.6	3.9	4.9	5.3	5.7
10–20	4.5	4.4	4.5	5.2	6.0	4.0	4.2	4.6	5.4	5.6	3.8	3.9	5.2	5.5	6.0
20–30	4.8	4.6	4.7	5.3	6.2	4.1	4.2	4.7	5.6	5.7	3.9	4.0	5.6	6.0	6.3
30–40	4.9	4.7	4.9	5.8	6.7	4.2	4.3	5.0	6.2	6.3	4.0	4.2	6.0	6.2	6.5
40–50	5.1	5.0	5.2	6.0	6.8	4.3	4.5	5.5	6.4	6.5	4.2	4.5	6.3	6.5	6.6

Table 3. **Organic soil pH_{KCl} in different forest site types**

Sampling depth, cm	Forest site types							
	P^n_a	P_a	P^n_b	P_b	P^n_c	P_c	P^n_d	P_d
0–10	2.5	2.6	2.9	3.4	3.8	4.6	5.2	5.3
10–20	2.6	2.7	3.0	3.4	4.0	5.1	5.3	5.5
20–30	2.7	2.7	3.1	3.3	4.1	5.2	5.4	5.6
30–40	2.7	2.8	3.2	3.3	4.1	5.2	5.5	5.7
40–50	2.8	2.8	3.3	3.4	4.2	5.3	5.5	5.7

of all soils studied in this zone. The content of phosphorus in soils of East Lithuania, as compared to Central Lithuania, is lower; however, it is higher than in West Lithuania. From the ecological viewpoint, the content of mobile phosphorus found in most soils of the country causes no major threat of water contamination. However, it should be borne in mind that the country has several large livestock farms which produce liquid manure and slurry. Their use for the fertilization of fields around the farms leads to a rapid increase not only in phosphorus but also in nitrogen content and may be highly hazardous to the stability of the natural environment.

CONCLUSIONS

1. The productivity of agricultural and forest crops is predetermined by soils, their granulometric texture, moisture regime, properties. From the point of view of agricultural crops, Cambisols and Calcareous Luvisols are more productive (by appr. 30%) than Albeluvisols of the same granulometric texture (loamy sand, sandy loam, clay soils) and by appr. 15% than Haplic and Albic Luvisols, while the latter are by 15% more productive than Albeluvisols. The productivity of forest soils is assessed by stand height (m), mean timber increment (m^3 ha^{-1}) as well as by the site index.

2. The fertility of agricultural soils strongly depends on moisture regime. Undrained or improperly drained soils produce only 65–70% of crop yield while Gleysols only 45–50% as compared to drained ones.

3. The highest acidification of soils is recorded in West Lithuania where the calcareous layer lies deeper (1.5–3 m). They have a more distinct elluvial horizon than the rest soils of the country, where deeper soil layers before intensive liming were highly or averagely acid.

4. Applying different rates of NPK fertilizers, surplus accumulation of N_{min} should be avoided in the soil after harvesting, because its excessive amounts under unfavourable climatic conditions are leached not only into deeper layers, but also into groundwater. To avoid this in soils in which a higher content of mineral nitrogen remains after harvesting, it is recommended to sow intermediate plants and to introduce their mass into the soil in spring.

5. Under the impact of different factors, a gradual degradation of soils is taking place in the country. It is caused by water, wind and chemical erosion, soil water-logging, strong acidification, compaction, contamination with heavy metals, pesticides, destruction of forest litter or its excessive accumulation, the high density of stands, establishment of pure spruce and pine stands, formation of ortzands in soils, podzolization and gleyzation processes. Fires are especially harmful to the soil.

6. Conditions for water erosion are most favourable on a hilly terrain. Every year such areas are deprived of 20–100 t/ha of the smallest soil particles and a high amount of nutrients. The steeper the slopes, the higher is the erosion and degradation of soils and the greater the loss of crop production. The most rational solution would be to afforest very hilly areas (>12°) or to sow grasses.

7. From the ecological viewpoint, the content of mobile phosphorus in most soils of the country causes no major threat of water contamination. However, the functioning large livestock farms produce high amounts of liquid manure and dung used for the fertilization of fields around the farms. This leads to a rapid increase of not only the content of phosphorus, but also of nitrogen, which may be very hazardous to the ecological stability of the natural environment.

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DIRVOŽEMIŲ IR JŲ SAVYBIŲ ĮTAKA AUGALIJOS PRODUKTYVUMUI BEI EKOLOGINIAM STABILUMUI

S a n t r a u k a

Straipsnyje panaudota gausi žemės ir miškų ūkyje sukaupta tyrimų medžiaga, susijusi su pagrindinėmis dirvožemių savybėmis. Laukų ir miškų augalijos produktyvumą lemia dirvožemiai, jų granuliometrinė sudėtis, drėgmės režimas, savybės. Išnagrinėta išskirtų šalyje pagal FAO klasifikaciją pagrindinių dirvožemio sistematinių vienetų įtaka žemės ūkio ir miškų augalijos produktyvumui. Rudžemiai ir karbonatingieji išplautžemiai žemės ūkio augalams našesni vidutiniškai 30 %, palyginti su tos pačios granuliometrinės sudėties (priesmėliai, priemoliai, moliai) balkšvažemiais, ir apie 15 % – nei paprastieji ir pajaurėjusieji išplautžemiai, o pastarieji apie 15 % – nei balkšvažemiai. Veikiant įvairiems veiksniams, šalyje palaipsniui degraduoja dirvožemiai. Degradaciją sukelia vandens, vėjo ir cheminė erozija, dirvožemio užmirkimas, didelis rūgštėjimas, suplukimas, užterštumas sunkiaisiais metalais, pesticidais, miško paklotės sunaikinimas arba didelis jos kaupimasis, per tankūs medynai, grynų eglynų bei pušynų veisimas, ortzandų susidarymas dirvožemyje, jaurėjimo ir glėjėjimo procesai ir ypač dirvožemį žaloja gaisrai. Ekologiniu požiūriu judriojo fosforo, esančio daugumoje šalies dirvožemių, kiekis kol kas nekelia didesnės grėsmės vandenims. Tačiau apie stambias gyvulininkystės fermas esančiuose dirvožemiuose sparčiai daugėja ne tik fosforo, bet ir azoto, o tai gali sukelti didelį pavojų gamtinės aplinkos stabilumui.

Parodyta didžiulė žmogaus ūkinės veiklos įtaka dirvožemio savybėms vykdant ilgalaikius tręšimo, kalkinimo, pelkinių dirvožemių sausinimo darbus, dėl kurių kartais pasekmės būna nepageidaujamos, destabilizuojama ekologinė pusiausvyra. Skelbiami duomenys galėtų praversti sprendžiant žemės ūkio ir miškų augalijos produktyvumo didinimo klausimus, racionaliai panaudojant potencines dirvožemių galimybes.

Raktažodžiai: augalijos produktyvumas, dirvožemio savybės, degradacija, augaviečių tipai