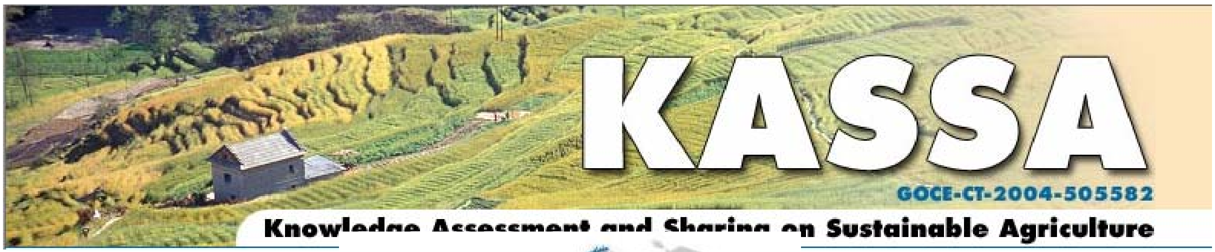

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Soil conservation in Estonia

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CONDITIONS OF OBTAINING RESULTS

Location and pedoecological conditions

The Republic of Estonia with a total area of 45215 km^2 (N 57^{o}30' - 59^{o}49' and E 21^{o}46' - 28^{o}13') is situated on the eastern coast of the Baltic Sea. Islands and islets form 9.2% of the territory and 4.8% is under inland water bodies. Therefore the importance of the coastline, with a total length of 3780 km, is significant.

Climatically Estonia belongs to the mixed-forest sub-region of the Atlantic-continental region of the temperate-zone, where there are typically warm summers and moderately mild winters. The annual average air temperature in Estonia is +4.7^o C (in February -6.6^o, in July +16.3^o C), and the annual average precipitation rate varies between 500 to 700 mm (Kivi, 1976). On these areas, depending on the composition of parent material and water conditions, the processes of argilisation, eluviation, podzolisation, gleyification and paludification in the soil cover are take place (Lillema, 1958; Kask, 1996; Reintam, 1997). Such combination of soil forming processes is typical to the *frigid-udic* and *frigid-aquic* pedoclimatic conditions. On uplands and higher parts of the relief with a coarse textured soil parent material, *frigid-aridic* soil forming conditions may be found.

On the bedrock surface of Estonia the Quaternary deposits are of uneven distribution. On the Ordovician and Silurian carbonate outcrops their thickness is usually less than 5 metres. On alvars they are almost non-existent. The Quaternary cover is at its thickest at the Haanja and Otepää heights (>100 m) and in the buried valleys of southern Estonia. The dominating soil parent materials in Estonia are derived from glaciation glacial and aqueoglacial quaternary deposits. Marine, alluvial and aeolian deposits are the products of reworked glacial and aqueoglacial sediments. The Pleistocene tills form 47.7% of the area. Glaciolacustrine (6.8%) and glaciofluvial (3.1%) parent materials are also widely distributed. A dominating part of Holocene marine deposits is located in lower parts of Estonia. Beside this the lacustrine, organogenous, fluvial and wind sediments can also be found (Raukas, 1995).

Soil maps of Estonia

Starting in 1954, a soil survey was carried out under the supervision of the Ministry of Agriculture (Kongo, 1957). During 1958-1991 the formation of soil databases as well as soil mapping and classification had immense success (Kokk, Rooma, 1989; Kokk, 1995). In co-operation between SE Estsurvey and Department of Soil Science and Agrochemistry (DSSA) of EAU the large-scale soil maps were prepared for the whole territory of Estonia. The soil cover was mapped using mainly the scale 1:10000. In 1989-91, besides inspection of arable land, forests and other civil territories' maps were completed. In an analytical programme the emphasis was put on the chemical and physical properties (analyses were done in EAU) apart from the characterisation of soil organic matter.

In the years 1998-2001, the large-scale (1:10000) soil map of Estonia was digitised by E.O. Map Ltd. in collaboration with soil surveyors using *MicroStation (MS)* software and linked with the soil geographical database. Main information displayed (by *MS GeoGraphics*, *MS GeoOutlook* and oth.*)* in the soil contour is: the SMU code, formulas of soil texture and humus profile (layers of soil organic matter accumulation, paying special attention to forest and natural grassland floor), as well as stoniness (fine and coarse stones separately). The application of geographic (contour) soil data is possible with *Microsoft Access*. The names of soil species (or SMU), which are done after ESC, may be easily converted into WRB (as well as USDA and other) systems, but this is rather approximate, as the one-to-one responder is non-achievable (FAO, ISRIC, ISSS, 1998).

The owner of the copyright and the distributor of Estonian large-scale soil map licenses is the Estonian Land Board (ELB). To find the area of interest fast, it is possible to use the Estonian comprehensive map, on which the Estonian territory is divided into quadrates (Estonian Land Board, 1998). It is also possible to use maps with names and boarders of villages, parishes and counties. The large-scale soil maps and databases related to it were traditionally widely used in agriculture and forestry, but lately they have been used more and more in solving problems of environment protection (Kõlli, 2002a).

On basis of large-scale soil maps the generalised middle scale maps for counties were compiled. The first comprehensive soil map of Estonia was compiled by A. Nõmmik (Nõmmik, 1925). This map was updated later many times from the agronomic-geologic aspect. The soil map legend is composed of soil groups characterised by soil texture, water conditions and profile development. Prepared by A. Lillema (1946), the soil map (1:400 000) was used as a basis for subdividing the country into soil regions according to texture and the lithology of the parent material (Lillema, 1946, 1958). In 1991, a synthesis of the soil distribution on the country level (as a 1:500000 and 1:200000) was prepared on the basis of a detailed soil survey (Kokk, Rooma, 1989). The 1:500000 soil map of Estonia was digitised in assistance with Soil Information Systems Laboratory (Cornell University, USA).

Soil cover composition

From the quality of soil cover as an essential natural resource depends not only the success in agriculture and forestry, but also the environmental status of the area (Table 1; Kokk et al., 1991). Among mineral soils (totally 76.8 % from whole territory) of Estonia, the dominating ones are *Luvisols (haplic, gleyic, cutanic), Albeluvisols (stagnic, umbric), Podzols (haplic, gleyic, carbic)* and *Cambisols (calcaric, gleyic).* Approximately one-third part of mineral soils is over moistened, because the *Gleysols (mollic, calcaric, histic)* form 27.1% of the total territory. The role of *Histosols (fibric, sapric)* is also remarkable (23.2%).

Large scale soil maps, as well as the series on the soil databases formed during the soil survey mentioned above, are intensively used and highly appreciated by specialists of soil science until today (Estonian …, 1974-89). Soil species, which is the smallest genetic subdivision in Estonian soil classification (ESC), is used as the large-scale soil mapping unit (SMU). The list of SMU contains approximately 90 soil species). The profiles of soil species in soil databases are characterised by profile formulas (occurrence of diagnostic horizons and their laying depth), whereas in case of forest soils the forest floor is also taken into account. For the characterisation of the properties of soil (diagnostic) horizon the following parameters were used: particle size distribution (texture); organic matter (carbon), total nitrogen and carbonate content; active (pH_{H2O}, pH_{KCl}), hydrolitical and exchangeable (H^+, Al^{+++}) acidity; cation exchange capacity; exchangeable bases (Ca, Mg, K) and the degree of base saturation; specific surface; bulk density and some others to a limited extent. In the calculation of soil species (or reference soils) mean characteristics (done separately for arable and forest soils) of the dominating soil species are divided into different varieties (subdivision of soil species in ESC) by their texture (sandy, loamy and clayey soils).

Table 1. The occurrence of soils, in % (Kokk et al., 1991)

Soil associations	Total	Forest area	Arable area
Rendzic **Leptosols** on limestone	1,2	0,8	0,8
Cambi-Rendzic&Gleyi-Rendzic **Leptosols** Calcaric&Calcari-Gleyic **Cambisols** on calcareous tills	6,3	2,5	11,1
Calcaric&Mollic&Haplic **Cambisols** Calcaric&Cambic&Haplic **Luvisols**	6,6	2,6	16,0
Calcari-Gleyic&Gleyic **Cambisols** Calcari-Gleyic&Gleyi-Cambic **Luvisols**	7,3	3,1	12,0
Stagnic **Luvisols** Glossic **Albeluvisols**	5,9	1,6	15,1
Haplic&Gleyic **Albeluvisols**	5,0	4,3	5,2
Ferric&Humic&Gleyic&Haplic **Podzols**	2,5	6,0	-
Calcari-Rendzic&Cambi-Rendzic **Gleysols**	1,4	0,7	0,9
Mollic&Eutri-Calcaric&Dystri-Calcaric&Luvic **Gleysols** on till	10,0	10,0	7,0
Calcic&Eutric&Dystric **Gleysols** on aqueous deposits	11,1	10,1	8,2
Eutri-Histic&Dystri-Histic **Gleysols**	4,7	5,3	2,5
Spodic&Umbric&Dystric **Gleysols**	2,9	4,1	0,8
Carbi-Gleyic&Histic **Podzols** Ferri-Dystric&Spodi-Histic **Geysols**	3,8	8,2	-
Eutric&Sapric **Histosols**	13,8	16,1	7,8
Dystric&Fibric **Histosols**	9,4	20,6	0,1
Eutric&Mollic&Salic **Fluvisols**	2,1	1,3	0,8
Cambisols&Luvisols, eroded	2,1	0,1	5,5
Anthrosols, Rangeland, Pits, Outcrops	0,2	1,0	-

Loamy (moderately coarse- and medium-textured) soils with the highest productivity form less than half (44.8%) of the territory. From the rest of the area, 26.7% of soils are sandy, 4.8% - clayey and 23.7% - peaty (Table 2).

Table 2. Texture of soils in % (Kokk et al., 1991)

Groups of soil texture	Total	Forest area	Arable area
Sandy or coarse textured soils	26,7	35,1	15,1
Sandy loam or moderately coarse textured soils	17,0	8,8	31,5
Loamy or medium textured soils	27,8	15,9	39,2
Clayey or fine textured soils	4,8	3,3	5,6
Peaty or organic soils	23,7	36,9	8,6

Soil organic matter and humus status of arable mineral soils

The problems connected with soil organic matter are relatively well studied in Estonia (Kõlli et al., 1996 and oth.). The problems treated in experimental researches are following: - research on soil humus status by different soil types; - investigations on SOM composition (fractional composition, well-humified part of SOM, role of fresh non-decomposed part); - the annual flux (originated from below- as well as from underground part of ecosystem) into soil; - the decomposition and humification of plant residues in various pedoecological conditions; - the role of accumulated in plant residues nutrition elements in re-establishment of soil fertility; - comparative ecological research of soil humus status in natural and arable soils; -

the recultivation of exhausted open pit quarries on the territory of oil-shale basin by humus soil.

The soil organic carbon (SOC) and soil organic matter (SOM) contents of Estonian postlithogenic mineral arable soils are analysed by 13 soil groups (Kõlli, Ellermäe, 2003). The SOC and SOM concentrations (g kg^{-1}) and pools (Mg ha^{-1}) for *Leptosols, Cambisols* (3 groups), *Luvisols* (2 groups), *Albeluvisols* (3 groups) and *Gleysols* (4 groups) were studied separately for humus cover (HC) and soil cover (SC). On the basis of different soil type characteristics and their distribution superficies the SOC and SOM pools for the whole Estonian arable land were calculated. It was revealed that in arable SC (forming 85,8% of total arable land) 86.4$\pm$13.1 Tg of organic carbon is sequestrated, from which 77.3% is situated in HC and 22.7% in subsoil. This quantity of SOC is sequestrated into 149$\pm$25 Tg SOM. The generalisation of the data received by different soil types, as well as elucidation of pedoecological regularities is done on the background of Estonian postlithogenic soil matrix.

For each type of arable mineral soil certain humus and soil organic carbon retaining capacity is characteristic, depending on its tillage activity, moisture regime, and carbonate and clay content. Differences between soils are clearly visible on postlithogenic soil matrix. Although the SOC and SOM contents and pools in HC and SC are soil type specific, they vary to a great extent, depending on variation of individual soil properties. Characteristics of soil type humus status indices may be used as benchmarks in arrangement of sustainable land use from the pedocentric viewpoint.

The quality of arable soil humus cover is characterised by humus cover types. With good agronomical properties neutral and pebble mild humus covers form 20-24% of total arable soils. The main constraints of dominating HC type (eluvic moder humous 27-30%) are high acidity and low humus content. Different organo-mineral humus covers (16-20%) have high potential productivity, but they must be managed in a way, which promotes the formation of a stable well-humified humus horizon from them.

Controlled by sustainable management, CO2 sequestration into the soil cover is based on adequate information about carbon retaining capacity of different soil types, as well as on monitoring their actual humus status.

ANALYSIS OF ECOLOGICAL AND ENVIRONMENTAL ASPECTS OF AVAILABLE RESEARCHES

Constraints of soil cover

The soil cover of Estonia belonging to the *frigid* pedoclimatic conditions has certain limitations in thermal resources and in the duration of the vegetation period. Depending of the precipitation-evaporation ratio, certain soils may each year be washed out, over-moistened or water logged. Typical constraints for large areas are high acidity, low humus quality and shallow profile of soils. In general the susceptibility of soils to water and wind erosion is not remarkable and salinization of soils as a constraint is absent altogether.

Some constraints are connected with certain soil properties as: the clay and humus content of the soil, extremely fine or coarse texture; deficiency of trace elements; great variability of soils; occurrence of the processes of paludification, podzolization and others, causing the degradation of soil fertility. Soils, which are situated in relation to groundwater resources on unprotected or poorly protected areas (northern and central part of Estonia) need controlled or restricted human activity for preventing worsening of water quality (Reintam, 1991; Raukas, 1996; Estonian…, 1997; Programme…, 1998). On dominating part of the territory the ground water is moderately or well protected and the conventional soil management may be used there. From the aspect of soil protection activities the monitoring and nature conservation must be taken as priorities. These aspects of soil functioning, which are essential from the point of view of Estonian soils conservation and sustainable use, must also be taken into account (Roots, Talkop, 1996; Kõlli, Lemetti, 1997; Programme…, 1998).

The features of soils and their functions degradation

In connection with the land reform as well as with a changing market situation for agriculture (by reducing), the large areas of arable lands are set aside. These areas covered with weeds may be classified from the point of view of agriculture as damaged or injured fields, on which the uncontrolled succession of plant-soil system begins. Reaching of stability by the formation of a forest association takes a lot of time. Contemporary laws do not protect the purposeful land use as well as protection of fertile arable land. But in reality the best way for protection soils is their sustainable use (Dosso et al., 1995).

The features of soil degradation occurring in Estonia are:

(1) on the entire territory- destruction of the normal functioning of the soil cover, degeneration of the biological diversity and activity, contamination by wastes, new anomaly (deficiency or exuberance) in trace element contents, loss of arable land (soil sealing) due to urbanisation;

(2) on arable lands - the depletion of nutrition elements from soils under the critical level due to unbalanced fertilisation, the loss of soil fertility due to the worsening of its humus status, the compaction of soils, appearance of water and tillage erosion, acidification, water logging on formerly drained hydromorphic soils;

(3) on certain soil types - wind erosion of over drained sandy and peaty soils, accelerated mineralization of peat on drained shallow *Histosols*, floodings on *Fluvisols*, - formation of ironstone hardpan on *Gleyic* and *Histic Podzols* and

(4) locally - soil pollution (military areas, lands around petrol stations and repair workshops), blockage of natural drainage in connection with road building, underground mining of oil shale, increasing alkalinity by flying cinders, dumping of oil shale mining residues, radioactive contamination.

The map of vulnerability and degradation of Estonian soils is prepared under supervision of L. Reintam in the framework of SOVEUR at the scale 1:2500000 (Reintam et al., 2001). On this map the soil pollution with heavy metals, water erosion, alkalisation, acidification, fertility decline by reduced organic matter content, compaction of subsoil, urban and industrial conversion, water logging as well as their impacts, degrees, causes and rates were assessed and described by the methodology elaborated in ISRIC (Batjes, 1997; van Lynden, 1997).

An important feature of arable soil degradation was the use of unfitting technology. One of them was very deep ploughing, which mixed the arable layer of soil in some places with podzolic, and on other places with very gravelly materials which result in the worsening of the humus status of soil. As a result of deep ploughing during approximately twenty years (1960-1980) the humus cover thickness of whole Estonian arable lands was increased by an average of 6-8 cm. In many cases this was also accompanied by the compression of the subsoil and the formation of rugged fields. Such degradations decreased the soil's actual productivity to a recognisable extent (Rooma, 1994; Kõlli et al., 1996; Estonian soils in numbers, 1985, 1987).

On lowland soils (different Gleysols) drained with tile or open ditches degradation has happened due to getting the established systems out of order. On these areas the worsening of soil water and redox regimes as well as water logging take place. In these cases their suitability rating for agriculture decreases, but the reaching of natural equilibrium of soil is always complicated.

Deterioration of soils is a great damage for national economy, as it is well known, how much work and finances was preliminarily spent for the cultivation of these areas for the purpose of farm fields. The most fertile soils were always situated around the large villages. In connection with industrial degradation of soils the newly cultivated areas were founded on soils, which have much more constraints, and needed therefore much more care and spending (Reintam, 1991).

For large areas of North Eastern Estonia soil degradation induced by chamber and open-pit-quarry mining of oil shale and phosphorite is characteristic. It has deformed the entire soil cover and deteriorated the physical, chemical and moisture relationships of soil (Reintam, Leedu, 1994; Reintam et al., 2001).

Some soil degradation processes, which are important globally (desertification, salinization, degradation by inappropriate irrigation), are absent in Estonia.

Soil pollution

Soil pollution is a regional problem and it can be detected around the industrial areas in the North East of Estonia. The main sources of pollution include wet and dry deposition of air pollutants originating from power plants, chemical enterprises, and from the production of construction materials. On the other areas it is caused by leaching pollutants from oils shale ash used for liming of arable soils. The main pollutants include cement dust, phenol, bens(a)pyrene, sulfur and nitrogen compounds, and some metals (National…, 1992). Geochemical mapping shows that the concentration of lead, uranium, cadmium and some other heavy metals in soils is above the maximum permissible limits in the industrial regions of North Eastern Estonia (Petersell, Ressar, 1993; Petersell et al., 1994, 1997). On most of the territory metal relationships are far above the level of maximum permissible limits. In some areas (Sillamäe, Maardu) radon originating from the surface is having considerable effect on the local radiation level reaching 5000 Bq m^{-3} in some places.

Areas with local soil pollution include those of the former Soviet army territories (airstrips, training polygons, places around fuel pipelines, lands under and around petrol stations, and repairing companies. According to official data these areas cover over 1.8% of the territory (National, 1992). Around Sillamäe and the military port of Paldiski the radioactive pollution is problematic.

Due to the changes in agricultural practice (re-establishment of small farms) the use of application fertilisers, pesticides and other chemicals has decreased. In connection with this the dangerous effect of chemicals on soil quality also decreases. Therefore measure to prevent overuse of chemicals is not actual in nowadays.

Soil compaction

On large part of the Estonian territory soils are mechanically damaged due to the use of heavy agricultural machinery which are unsuitable for the local soils and used at a wrong time (Nugis, Lehtveer, 1991). Land improvement activities, which were carried out during the collective farms' period, have also influenced the soil fertility and its water and oxygen regime towards a positive direction in several cases.

During last couple of years a lot of scientific works upon problems connected with arable soil compaction was published by J. Kuht, E. Reintam and others. Most of these works are dedicated to analysis of soil compaction consequences as: (1) - changes in ecophysiology of planr cover (Kuht, 1994; Kuht et al., 1999, 2001, 2003; Kuht, Reintam, 2004; Reintam, Kuht, 2002, 2003) and (2) – changes in plant cover (especially in weed) composition (Reintam, Kuht, 2004a, 2004b; Edesi et al., 2004 and oth.). From the other hand many researches are dedicated also to restoration of ecologically optimal status of compacted soils. For example restoration soil good status by biological methods (Kuht, Reintam, 1998, 2001; Kuht et al., 2004a, 2004b; Reintam, Kuht, 2003; Reintam et al., 2004).

Erosion and tillage erosion

Due to the local meteorological conditions (little precipitation in spring time; low rainfall intensity; relatively short vegetation period; character of soil parent material; relief of landscape) the intensity of natural erosion is not high. The results of a large scale mapping of the Estonian soil cover ascertained that the water erosion has a remarkable soil degradation influence (sheet and rill erosion) mainly to arable soils in the south-eastern part of Estonia. The investigation of water and tillage erosion enables to declare the presence of tillage erosion of these arable soils, which are not recognised as areas vulnerable to erosion (Kõlli, Ellermäe, 1999; 2003).

Soils damaged by erosion form 5.5% of Estonian arable lands. Water erosion has a marked influence on hilly end moraine areas. In these erosion hazardous counties (Võru, Valga) 32–37% of arable soils are influenced by erosion. Eroded areas of arable soil cover are composed from synlithogenic slightly and moderately eroded *Luvisols, Cambisols, Albeluvisols* and *Regosols*, located on uplands, as well as from auto- and semihydromorphic (gleyic) deluvial *Luvisols* and *Albeluvisols,* situated on convexities and on lower parts of the landscape. The severely eroded (mainly *Regosols*) and hydromorphic deluvial soils (*Cumulic&Endogleyic Cambi-&Luvi-&Albeluvisols* and *Cumulic Gleysols*) are spatially limited. These areas may be classified as loamy sand and sandy loam soils.

On large-scale (1:10000) soil maps it is impossible to assess the diversity of soil cover on erosion hazardous areas, as in reality continuums (from eroded soils to deluvial ones) exist. For this reason, we used the soil transect methods for the assessment of the variability of the soil humus properties. The humus status of soils influenced by erosion (eroded and deluvial) is very variable (humus content varies between 12–45 g kg^{-1}, humus stock between 39 and 210 Mg ha^{-1}). Besides erosion, excessively deep ploughing and intensive tillage also deteriorates the humus status of arable soil.

The observed average decrease of humus stock due to erosion ranges between 27–71 Mg ha^{-1}. The average increase in accumulation areas is 31–114 Mg ha^{-1} of humus. The balance of humus on areas influenced by erosion seems to be positive, thanks to deluvial soil which contains humus stocks (from 35 to 110 Mg ha^{-1}) eliminated from natural circulation (buried). Humus stocks' relocation coefficients demonstrate 2.2–3.9 fold differences between eroded and deluvial soils as well as their relocation character in relation to transitional soil epipedon humus stock.

SIGNIFICANCE AND IMPACT OF THE RESULTS OBTAINED

The current attitudes toward soil degradation

The only governmental institution in Estonia is SE Estsurvey whose information on soil survey originates also from earlier periods. In present day the adequate soil information system needed for soil cover sustainable management is not yet established and therefore it is difficult to have an overview of the actual status of soil cover. Estonia has two scientific institutions where soil science topics are dealt with. The leading one of them was the DSSA of EAU. At the Institute of Agriculture mainly the projects on arable soil monitoring as well as research on agrotechnology are developed. It is symptomatic that Estonian government puts much more attention to the conservation of water and air resources in comparison with soil resources (Agenda 21, 1992; Michelson, Peterson, 1996; Estonian…, 1997).

Farmers are interested in the development of a modern state supported extension service. For this the extension service must be related with the university, where in addition to information about Estonian soils, the recent advantages of fundamental soil science may be widely used. The farmers are primarily interested in the suitability of soils for crops, and about current nutrition elements, humus and calcium status in soils. They are also interested in new ways of moderate use of chemicals and fertilisers, as well as in the production of naturally pure plant and livestock products. Most Estonian farmers do not have enough financial resources for using new technology and machinery suitable for concrete soils or specific local area.

The society, knowing and respecting well known global theses in relation to soil, is often not able to adequately appreciate their validity or invalidity locally. International projects, the activities connected with soil science organisations, the soil protection policies within the European Union (Europe's…, 1998) and the soil monitoring are widely introduced in some works (Kõlli, 1999a). Special interest is given to the soil charters (Worlds, European) as well as to the project of soil convention (European…, 1972; World…, 1981).

Knowing the problems on the global level may be explained by globalisation of information and access to the Internet. At the local level is well known that soils may be degraded, but to what extent, what is the mechanism of degrading, which soils are more sensitive to degrading- all this is not clear. Little awareness of the problems on the regional or local level is from the one hand caused by inadequate knowledge about local soils, as well as their functions and constraints. On the other hand it is due to non-adequate appreciation of soils as natural resources, and their importance in the environmental status. It is not enough to know only that soil is a slowly renewable natural resource. Everyone must have the knowledge about possibilities to contribution for these processes by different soil mapping units.

Estonian society's awareness on the importance of soils in forming ecologically stabile environment is not widespread in public opinion. This is unfortunately valid also for those who use or manage the soil directly. We support and agree with paragraph 8 of Klingenthal Declaration, and suppose that it deserves the whole world's understanding

(Declaration…, 1998). In this sense we welcome an international solidarity against the soil deterioration (Dosso et al…, 1995).

Crop rotations and soil management

The annual input of autochtonic phytomass and retained organic residues in arable soil varies to a large extent due to crop rotation, soil management and climatic characteristics. The agronomic activity may and must control the stability of SOM in arable soil. An optimal crop rotation and application of extra organic amendments are the agronomic keys for enhancement of annual inflow of organic residues into the soil (Kanal, Kõlli, 1996).

In many experiments the influence of ploughing depth on the yield and soil were studied. It was elucidated that the deep ploughing is not justified on most of arable soils (Vipper, Voor, 1998). Preventive (as effectiveness of plough and stubble cultivation) and mechanic control of weeds were studied on different soils and in different management conditions (Vipper, Voor, 1998; Kuill, Lauringson, 1998; Lauringson et al., 1998). It was stated that increasing of soil fertility is important component of complex weed control (Kuill, 1994; Kuill et al., 1995; Kuill, Lauringson, 1998).

In pedoclimatic conditions of Estonia were studied following connected with soil management problems: - the importance of mixed crops in organic farming (Lauk et al., 2001); - cereal yields in conditions of organic farming (Köster, Ellermäe, 1999); - what to do with abandoned fields (Kuill et al., 1999; Lauringson, Talgre, 2003); - direct sowing of winter cereals (Vipper, Lauringson, 1994); - quality of arable land (Kask, 1975; Roostalu, 2000; Roostalu et al., 2001; Roostalu, Suigussaar, 2001); - application of fertilizers (Roostalu et al., 1999); - weed control (Laurinson, Kuill, 1995; Lauringson et al., 1999, 2001, 2004); - influence of agrotechnology on the quality of soil (Vipper, Põder, 1994; Vipper, 1999; Lauringson et al., 1999, 2004); - agronomical aspects of grain growing technology (Viil, Võsa, 2004); - dependence of availability of nutrition elements from tillage and crop rotations (Lauringson et al., 2004).

Other ecological researches

Different agro-ecological problems were studied on grasslands. For example the comparative research of conventional and organic grasslands (Geherman et al., 2001, 2003; Geherman, Ellermäe, 2001; Geherman, Viiralt, 2004 and others). From connected tightly with CA and OF researches must be mentioned also: - the integrated pest control (Hiiesaar et al., 1994 and oth.); studying of peat soil properties for their sustainable use (Noormets et al., 2004); the influence of liming to the ecology of acide arable soils (Loide, 2004), Biological recultivation of oil-shale fields (Kaar et al., 1991) and others.

Prospects for different action projects

The most important driving force for development of conservation agriculture is international collaboration. Estonia expects regional (Baltic and Scandinavian countries) co-operation in the field of scientific research and education. This should include the arrangement of scientific forums; establishment of joint projects in the scientific research and in extension services. International solidarity helps to use the advantages of fundamental soil science and to introduce the importance of regional problems.

The priorities in struggling against the soil degradation may be treated from two aspects. In case of arable soils the key factors are the arrangement of a closed turnover of nutrition elements, the compensation of the annual losses of soil organic matter, the elimination of the causes of soil contamination, the protection of the biological activities on suitable level, and keeping soil humus cover as well as established drainage systems in good order. As for the forest soils, it is very important to conduct the plant-soil relationships into a state, which is characteristic to soil properties, and at the same time increasing the biological activity step by step. Such kind approach is called pedocentric and for prerequisite of this is well available data on soil cover properties.

Legislation connected with sustainable use and protection of soil cover

Estonia has not yet special laws for the arrangement of soil cover protection. Laws, which are established for other purposes, but relate to soils indirectly, can be applied. The following could be mentioned here: Wastes Act (1992), Environmental Fund Act (1993), Act of Pollution Charges (1993), the Act on the Rights of Using Natural Resources (1993), Act on Sustainable Development (1995) and several other laws and regulations having indirect impact to sustainable use of soils (Raukas, 1996; Legislation…, 1995; Tarasofsky, Krämer, 1998). In the Constitution of Estonia, article 53 defines that "Everyone is responsible for the preservation of the human and natural environments and must make good any damage that has been caused to them". From the aspect of soils as natural resources this means that they must be used and protected in the way that they may fulfil their main functions continuously. There is a strong need for codes and legislation related to soil conservation. Examples of this may be found in different sources (Bär et al., 1998; Code…, 1993).

Land use and its dynamics during the last century and decade

Agricultural land forms approximately 32% and forests 45% of the territory. The main trends in Estonian land use dynamics have been the decrease of agricultural land (from 65% in 1918 to 30% in 1994) and the increase (from 21% to 43%) of forested areas (Mander *et al.*, 1995). By 1994 66% of arable land had been drained, from which 87% or 643000 ha was tile drainage (Soovik *et al.*, 1996).

During the last couple years the land use policy of Estonia has been unfavourable for sustainable (adequate to its properties) and intensive management of its soil resources. As a result of this the decreasing of efficiency in soil use and the deterioration of arable soil quality are happened (Roostalu, 2000). The main changes in the properties of soils in connection with the land usage during recent decades are the following: the quantity and openness level of biogeochemical turnover of biophilous elements on arable soils have decreased; the composition and properties of epipedons on set aside areas have become more similar to natural ones; the quality of humus has deteriorated as a result of a decrease in fertilisation load and liming (Kõlli, 1998b).

The influence of land-use change to soil cover properties and functioning

At present the following problems induced from the pedocentric standpoint of sustainable land use are studied in Estonia (Kõlli, 1996): - the suitability of soils for agricultural crops; - the management of soil cover depending on its humus status; - the timing of plant residue mineralization with plant cover nutritional needs; - location of soil organic matter in the soil media; - the subsidizing of nutrition elements being in critical states in dependence of soil and plant kinds; - the agroecologically sound application of chemicals and fertilizers; - treating of naturally developed soil cover as benchmark.

Land-use change influences first of all the soil humus cover or epipedon, which is as a transition layer between vegetation and soil in natural conditions and is mainly mechanically manipulated and from aside subsidated soil cover part in cultivated areas (Kõlli et al., 2004). Clearly visible differences between forest and arable soils can be seen in epipedon fabric. On arable mineral soils in conventional soil management conditions the development of exogenic humus covers is prevented due to regular soil tillage. In most cases the thickness of arable humus covers (endogenic) surpasses that of natural areas. If we take into account also the epipedon volume weight, which is always higher in arable soils, then it is clear that soil mass of arable soil humus cover overpasses the same of natural ones.

For sustainable soil management it is useful to know the best humus cover types from the aspect of biological activity, ecosystem productivity and environment protection ability for local pedoclimatic conditions (Kõlli, 1994, 1996). From the agronomic aspect the best humus covers belong to the neutral mild humus cover type, the main constraints of others may be high acidity, low humus content, raw-humous fabric and wet moisture conditions.

It should be noted that in naturally proceeding stabilisation processes the decrease of SOC concentration in topsoil is not always accompanied with the decrease or loss of humus cover SOC pools, as at the same time the depth of humus cover increases (observed effect of dilution) and also the humus binding (stabilising) extent increases. In this context the question of the efficiency of non-tillage management may be arisen. Following natural models or patterns seems optimal to the ameliorative organic residue on the soil surface, with surface density between 3-5 Mg ha^{-1}. The expedient residue's quantity ought to attain nearly 100% of the coverage of soil, contain nutrition elements corresponding to the medium input level and must be equilibrated from the aspect of C:N as well as mutual nutrition elements ratios.

Soil cover thickness is also not so much influenced by land-use, but first of all a peculiarity connected with soil type and local conditions. SOC pools demonstrated an important role of subsoil in carbon sequestration. From this aspect there are also no clearly visible regularities in the differences between arable and forest land soils or the connection with land-use change.

DISCUSSION AND PROPOSITIONS

Estonian society's perception of soil

Environment protection role of soil cover needs much more reclamation as it helps to arrange ecologically sound and without risk landscape management and form with optimal biodiversity landscapes (Kõlli et al., 2002, 2004). But at the same time it must to say that very injurious for sustainable land use is one-sided evaluation of organic agriculture. There must be emphasized the each year soil expenses compensation requirement as in opposite case the soil degradation take place. The nowadays soil cover research level and available information are the good requisite for arrangement ecologically sound and sustainable land use and agricultural activity.

For the modernizing of land management are urgent need to propagation new advantages, as country side society is traditionally interested from possibility to see personally the functioning of new technology in reality. In the field of agriculture the society needs much more quality and less mistakes. The Estonian society as a whole needs a well-defined and realistic conception in land management. The society must be able to join the global and local soil managing strategies. In small farms is more difficult to take soil suitability into account for the growing of crops and for the use of effective soil management systems.

Media often exaggerates global problems connected with soil to not emphasising at the same time very essential problems of locale area. Appropriate and sustainable land use must be oriented to resolving of area environmental problems as well as self-providing needs of food and technological materials.

Development of soil survey

A supported by the government soil survey was initiated 1954 for the assessment of the country's soil resources for their improved management, optimised fertilisation and effective land use planning. Intensive research and experiments were conducted to determine the suitability of soil for major food crops and changes in land use as well as in connection with extension work. With the increase of farm sizes the applications of soil survey data have broadened considerably, mainly in connection with amelioration (drainage, liming, application of organic fertilisers) of arable soils. In addition to agriculture, applications are being made in connection with environmental and various other land use issues: analysis of the impact of agrochemicals on soil and water quality under different farming practices; nitrate leaching susceptibility of different soils; environmental impact assessment of different types of land use; decision support systems for nature conservation; adjustments of land use in the framework of the European set-aside policy. Nowadays the emphasis of land evaluation has shifted from the production factors to environmental concerns (Kõlli, 1999b).

The main aim of sustainable soil use and management was to preserve soil quality and functions (Kõlli, 2001). An attention was paid to the development of systems that are productive, but at the same time economic and protective. They should to be in harmony with the soil, and prevailing climate, as well as environmentally benign. The main scientific basis for sustainable land use is formed by the knowledge of various branches of soil science. The soil survey should be continued by emphasising the research of newly set aside areas and also by modernising the soil survey technologies.

The main research topics and recent results

In Estonia, the biological and ecological aspects of soil organic matter researches are of utmost importance (Kõlli *et al.*, 1996). These embrace a lot of processes connected with the flux of soil organic matter (as storage of energy and nutrition elements) through the humus cover. The humus cover is directly bound and significantly influenced by vegetation and soils. Both influences are integrated in the humus cover properties and may consequently be determined by a certain type of humus cover (Kõlli, 1992). The knowledge on the types of humus cover enables to evaluate the humus status of soils and its adequacy towards the existing pedoclimatic conditions. For distinguishing the epipedon types of Estonian arable soils the following criteria were used: distinctness and stratification of humus cover; fractional composition of soil organic matter and its connection with mineral particles; the existence of contemporary geological processes; percentage, pool and quality of humus; soil texture, structure and calcareousness; composition of edaphon and biological activity; agrochemical properties and used agrotechnology.

The SMU of ESC were developed to become more logical and expedient (Kõlli, 1997, 1998a). The comparison of ESC with of WRB and USDA indicates the following: (1) the dominating number of criteria is similar; (2) some of the criteria are not yet used in ESC, but they should be used in the future; (3) some of them are not applicable due to the specific local conditions and (4) some criteria are distinctive only to ESC. It is obvious that ESC needs updated renovation and must have a good correlation with internationally recognised soil classification systems. It helps to change the related scientific information, and develop international co-operation.

In the evaluation of environmental protective ability of soil cover the active and passive aspects of environmental protection abilities of soils were taken into account. For grouping soils by this ability the epipedon and soil profile thickness, character of epipedon, textural properties, indices of specific surface area, cation exchange capacity, calcareousness and biological activity were used (Kõlli, 1999b; Kõlli et al., 2004). As result of this analyse soils were divided into five groups: (I) with good to (V) faible environmental protective ability. Estonian soil cover has sufficiently soils, which have a high environmental rating. This offers a good possibility for developing the intensively managed agricultural crop rotations.

Since 1965 a large number of pedoecological investigations have been made in order to build up a national database on soil productivity as well as chemical properties and other characteristics of Estonian soils (Reintam, 1970, 1971, 1973, 1975 and oth.). Studies on the functions of plant-soil systems at the ecosystem level, and interactions of organic and mineral constituents in soils are on a relatively good level. Researches on ecological fundamentals of fertilisation and application of organic and nitrogen fertilisers in crop rotation should also be mentioned (Kanal, Kuldkepp, 1999). Attention has always been paid to turnover of substances between soil and plant cover, a complex characterisation of Estonian soils, ecologically sound and sustainable use of soil cover (Estonian…, 1974-1989). Investigation on soil ecology, biota and biological activity of soils has been started recently. The physical and hydrophysical properties of soils were experimentally studied some decades ago (Kitse, 1978). Now the data on pedoclimatic conditions and their consideration in soil management are elaborated intensively by H. Roostalu et al.(1999).

It is also regrettable that the monitoring of Estonian arable soils was stopped for the long time but now it started newly or is continued on some areas. Due to the absence of financial support by the government, several soil science problems remain unsolved.

REFERENCES

Agenda 21. 1992. United Nations. UN Doc., A/Conf., 151/26, Vol.I-III.

Bär S., Hollerbuhl S., Krämer R. A. 1998. EC Policy and Legislation Related to Soil Conservation: Initial Overview. Ecological CIEEP, 22 p.

Batjes N. H. 1997. Methodological Framework for Assessment and Mapping of the Vulnerability of Soils to Diffuse Pollution at a Continental Level (SOVEUR Project). Report 97/07, ISRIC, 34 p.

Code of Good Agricultural Practice for the Protection of Soil, 1993. MAFF, Welsh OAD.

Declaration of Klingenthal III on Soils. 1998.

Dosso M., Lahmar R., Ruellan A. 1995. The Soil Campaign. Initial P roposals.

Edesi, L., Kuht,J., Reintam, E. 2004 . Soil compaction after-effect on quality stalks of barley and weeds by dry weather conditions. – Agronomy 2004. Transactions EAU, 219:22 – 24.

Estonian Land Board. 1998. System of map sheets. http://www.maaamet.ee/eppknum.htp.

Estonian National Environmental Strategy, 1997. EEIC, Tallinn.

Estonian Soils in Numbers, 1974-89. SPI "Estonian Agriproject", Tallinn, I-1974; II-1978; III-1983; IV-1985; V-1985; VI-1987; VII-1988; VIII-1989.

European Soil Charter, 1972. Council of European Resolution (72) 19.

Europe's Environment: The Second Assessment - an Overview, 1998. EEA, Copenhagen.

FAO, ISRIC&ISSS. 1998. World Reference Base for Soil Resources. World Soil Resources Reports 84. Rome. 91 pp.

Geherman V., Viiralt R., Ellermäe O. 2003. Comparison of leys on conventional and organic farms. Agronomy Research 1, 11-16.

Geherman, V. Viiralt, R. 2004. Comparison of legume-rich leys in conventional and organic farms. – Agronomy 2004. Transactions EAU, 219:148 – 150.

Geherman, V., Ellermäe, O. 2001. Biodiversity of conventional and organic grasslands and the content of plant nutrients in soil. Transactions EAU, 212:93 – 96.

Geherman, V., Viiralt, R., Parol, A. 2001. Intensively used and organic grasslands: Comparison on the basis of the yield potential and forage quality. – Transactions EAU, 212:65 – 68.

Hiiesaar, K., Lauk, Ü., Metspalu, L. 1994. Plant toxins for pest control. Transactions EAU, 178:137 – 139.

Kaar E., Leedu E., Kitse E. 1991. Biological Recultivation of the Estonian Oil-Shale Fields. (L. Reintam, Ed.) Problems of Soil Protection in Estonia. Tallinn, 108-121.

Kanal A., Kõlli R. 1996. Influence of cropping on the content, composition and dynamics of organic residue in the soil of the plough layer. Biol Fertil Soils 23:153-160.

Kanal A., Kuldkepp P. 1999. Influence of Different Fertilization Systems on the Sulphur Content of Podzoluvisols and Wheat Grain. Transactions AAS, 9.

Kask R. 1975. Estonian Land Resources and Agricultural Quality. Tallinn.

Kask R. 1996. Soils of Estonia . Tallinn.

Kitse E. 1978. Soil Water Valgus, Tallinn.

Kivi K. (Ed.) 1976. Agroclimatic resources of Estonian SSR. Valgus, Tallinn, 142 p.

Kokk R. 1995. Soil Distribution and Properties. (A. Raukas, Ed.) Estonia. Nature. Valgus, EEK, Tallinn, 430-439.

Kokk R., Reintam L., Rooma I., and Sepp R. 1991. Forest soils in Estonia. In (S.V. Zonn ed) Degradation and rehabilitation of forest soils. Nauka, Moscow, pp. 33-36.

Kokk R., Rooma I. 1989. A New Map of Estonian Soils. Estonian Nature, 10: 636-640.

Kõlli R. (Ed.) 1998a. Problems of Estonian Soil Classification. Transactions EAU, 198. Tartu.

Kõlli R. 1992. Production and Ecological Characteristics of Organic Matter of Forest Soils. Eurasian Soil Science, 24:6, 78-91.

Kõlli R. 1996. The pedoecological aspects of sustainable crop production. Transactions EAU, 187A: 51-54.

Kõlli R. 1997. Soil Classification as an Essential Tool in Soil Cover Research. Transactions EAAS, 4, 39-42.

Kõlli R. 1998b. Soil Cover of Estonia as Influenced by Present-Days Land Use Policy. Transactions EAAS, 6, 47-50.

Kõlli R. 1999b. Soil Cover as Stabilising Environmental Status Medium. Transactions EAU, 203. Tartu.

Kõlli R. 2002. Estonian society's perception of soil at the post-soviet period. In J.L. Rubio, R.P.C. Morgan, S. Asins, V. Andreu (Eds.) Man and Soil at the Third Millennium. Vol I, ESSC, Geoforma Ediciones, Logrono, pp. 287-298.

Kõlli R. 2002a. Large-scale digital soil map of Estonia and its application for soil conservation purposes. ESSC, Newsletter, 2:7-9.

Kõlli R. I999a. International Projects and Conventions on the Sustainable Use of Soils. Transactions EAAS, 9, 61-64.

Kõlli R., Ellermäe O. 1999. The Relative Importance of Tillage Translocation and Water Erosion in the Deterioration of Soil Humus Status. Tillage Erosion and Tillage Translocation. Abstracts. Leuven.

Kõlli R., Ellermäe O. 2003. Humus status of postlithogenic arable mineral soils. Agronomy Research 1(2), 161-174.

Kõlli R., Lemetti I. 1997. Governmental Soil Monitoring Program of Estonia. Manuscript, Tartu, 37 p.

Kõlli R., Lemetti I., Kanal A., Penu P. 1996. Researches on Soil Organic Matter at the Department of Soil Science and Agrochemistry through the Times. Transactions EAU, 187. Tartu.

Kõlli, R. 1994. Classification of arable soil humus cover. Agronomy 1994. Transactions EAU, 178: 82 – 86.

Kõlli, R. 2001. Natural and social prerequisites for contemporary conservation agriculture in Estonia. Transactions EAU, 212:9 – 14.

Kõlli, R., Ellermäe, O., Soosaar, K. 2004. Soil cover as a factor influencing the status of the environment. Polish J. Soil Science, Vol. XXXVII/I, 65–75.

Kõlli, R., Lemetti, I., Penu, P. 2004. The influence of land-use change to soil cover properties and functioning. – 4th International Congress of ESSC. Proceedings Volume, Budapest, 9–12.

Kongo A. 1957. On Soil Mapping in Estonia. EGS Year-Book 1957.

Köster, T., Ellermäe, O. 1999. The Investigation of Cereal Yields and Soils in Estonian Ecofarms. – Transactions EAU, 203:74 – 78.

Köster, T., Kauer, K., Tõnutare, T., Kõlli, R. 2004. The management of the coastal grasslands in Estonia. In: Coastal Environment V incorporating Oil Spill Studies. (C.A. Brebbia, J.M. Saval Perez, L. Garcia Andion ja Y. Villacampa eds.), WITpress, Southampton, Boston, 45–54.

Kuht J. Reintam E., Loogus H., Nugis E. 2003. Changes of nitrogen assimilation and intracellular fluid pH in plants of barley depending on bulk density of compacted soils. – *Agronomy Research*, 2003, 1(2), 139–144.

Kuht J., Reintam E. 1998. About restoration of ecological status of a super compacted soil by biological methods. *Proceedings of the Workshop on Sustainable Tillage Systems.* USDA-ARS National Soil Dynamics Lagoratory, Agricultural Engineering Department, Auburn University, and Agronomy and Soils Department, Auburn University. Auburn, AL, July 8–10, 41–50. http://msa.ars.usda.gov/al/auburn/nsdl/workshops/cigr98/proceedings/kuht.html

Kuht J., Reintam E. 2001. The effect of deeprooted plant growth on the qualities of overcompacted soils. 632–636 pp. In: D.E. Stott, R.H. Mohtar, and G.C. Steinhardt (eds). Sustaining the Global Farm – Selected papers from the 10th ISCO Meeting, May 24-29, 1999, West Lafayette. ISCO cooperation with the USDA and Purdue University, West Lafayette,

Kuht J., Reintam E. 2004. Soil compaction effect on the soil physical properties and the content of nutrients in spring barley (*Hordeum vulgare* L.) and spring wheat (*Triticum aestivum* L.). – Agronomy Research 2, 2, 187–194.

Kuht J., Reintam E., Nugis E. 2001. Changes in nutrient content of spring wheat (*Triticum aestivum* L.) and some weed species as affected by soil compaction. Proceedings of the 1st International Conference of BSB of ISTRO & Meeting of Working Group 3 of the INCO-COPERNICUS Concerted Action on Subsoil Compaction, "Modern Ways of Soil Tillage and Assessment of Soil Compaction and Seedbeed Quality". Tartu, August 21–24, 2001, 188–197.

Kuht J., Reintam E., Nugis E., Edesi L. 2004a. About effect lupine (*Lupinus luteus*) root system on the properties of compacted soils. – Proceedings Volume of 4th International Congress of the ESSC, 25–29 May, Hungary: HAS 341–344.

Kuht J., Reintam E., Nugis E., Loogus H., Edesi L., Puust J. 2004b. Some criterias to barley (*Hordeum vulgare* L.) growth by soil stress conditions. – Proceedings of 4th International Conference on Land Degradation, 12–17 September 2004, Spain: Quaderna Editorial. CD-ROM

Kuht, J. 1994 The influence of agricultural background on the effect of minimization of pre-sowing soil cultivation. Agronomy 1994 Transactions EAU, 178: 45 – 48.

Kuht, J., Ries, M., Reintam, E. 1999a. About influence of soil properties on the composition of phytocoenosis on compacted soils. – Transactions EAU, 205:18 – 23.

Kuill T., Lauringson E. 1998. Integrated system of weed control: I. Factors limiting the weed control efficiency. Transactions EAU, 199: 18-23.

Kuill, T. 1994. Complexes of weed control in agroecosystem Transactions EAU, 179:50 – 52.

Kuill, T., Lauringson, E., Talgre, L. 1999. Abandoned fields in biosystem. Transactions EAU, 205: 24 – 33.

Kuill, T., Vipper, H., Lauringson, E. 1999. Wheatless field – heavy crop. – Transactions EAU, 205:5 – 12.

Laidna, T., Viiralt, R. 1994. Biological and mineral nitrogen on the grassland. Transactions EAU, 179:53 – 56.

Lauk, E. Lauk, R. Lauringson, E. Talgre, L. 2001. The place of mixed crops in enviroment-friendly farming. Transactions EAU, 212:104 – 111.

Lauringson E., Kuill T., Talgre L., Vette M. 1998. The influence of different ways of stubble cultivation on weediness of cereals. Transactions EAU, 199: 24-30.

Lauringson E., Talgre L. 2003. Problems of abandoned fields. Agronomy Research 1, 63-67.

Lauringson E., Talgre L., Roostalu H., Vipper H. 2004.The effect of tillage and crop rotation on the content of available nitrogen, phosphorus and potassium. Agronomy Research (2)1, 63-70.

Lauringson, E. Kuill, T., Talgre, L., Vipper, H., Hirsnik, L. 2001 Long-term tillage and rotation effects on the weed seedbank. – Transactions EAU, 21:120 – 127.

Lauringson, E., Kuill, T. 1995. About some problems of weediness and weed control. Transactions EAU, 182:76 – 82.

Lauringson, E., Kull, T., Vipper, H., Talgre, L. 1999. The influence of crop rotation and chemical weed control on productivity, weediness and consuption of nutrients by plants in agrophytocoenosi. – Transactions EAU, 203:90 – 95.

Lauringson, E., Talgre, L., Kull, T., Hirsnik, L. 1999. Effect of agrotechnology on the density of earthworms. – Transactions EAU, 203:96 – 101.

Lauringson, E., Talgre, L., Vipper, H. 2004 . The effect of crop rotation and weed control on soil humus content. – Agronomy 2004. Transactions EAU, 219:13 – 15.

Legislation on Sustainable Development, 1995. RT I, 31, 384.

Lillema A., 1946. Bref Soils Description to the Soil Map of Estonia. (1:400 000). Tallinn.

Lillema A., 1958. Soils of Estonia. Tallinn.

Loide V. 2004. About the effect of the contents and ratios of soil’s available calcium, potassium and magnesium in liming of acid soils. Agronomy Research (2)1, 71-82.

Mander Ü., Palang H., Tammiksaar E. 1995. Landscape Changes in Estonia During the 20th Century. Year-Book EGS, Vol.29.

Michelson A., Peterson, K. (Eds.), 1996. Environmental Policy of Estonian Agriculture. SEI, Tallinn, 80 p.

National Report of Estonia to UNCED, 1992. EME, Tallinn.

Nõmmik A. 1925. Agronomy, 6.

Noormets, M., Köster, T., Tõnutare, T., Kauer, K., Kõlli, R., Karp, K. 2004. Determination of microbial activity and nitrogen and carbon forms in a peat soils in Estonia. – In: Geo-Environment 2004. International conference on Monitoring, Simulation and Remediation of the Geological Environment. 5–7 July 2004, Segovia, Spain, 59–68.

Nugis E., Lehtveer R. 1991. On Spreading of Soil Degradation by Machines in Estonia. (L. Reintam, Ed.) Problems of Soil Protection in Estonia. Tallinn, 63-75.

Petersell V., Ressar H. 1993. Heavy Metals in Estonian Soils. Eesti Loodus, 4:151-153.

Petersell V., Ressar H., Carlsson M., Mõttus V., Enel M., Mardla A., Täht K. 1997. The Geochemical Atlas of the Humus Horizon of Estonian Soils (with 39 maps) GSE, GSS. Tallinn-Uppsala.

Petersell V., Ressar H., Mõttus V., Olsson A., Unt L., Võsu M. 1994. Geochemical Atlas of the Humus Horizon of Soil and upper Layer of Peat Deposits of Northeast Estonia. Tallinn-Uppsala.

Programme for Environmental Activity in Estonia, 1998. Manuscript, EME, Tallinn, 97 p.

Raukas A. (Ed.) 1996. Estonian Environment: Past, Present and Future. EME, EIC, Tallinn, 192 p.

Raukas A. (Ed.)1995. Estonia. Nature. Valgus, EEK, Tallinn.

Reintam E., Kuht J. 2002. Impact of soil compaction and sowing density of barley on uptake of nutrients. *Proceedings of International Scientific and Practical Conference "Scientific aspects of organic farming"*. LUA, Faculty of Agriculture. March 21–22, 2002, Jelgava, Latvia, 167–171.

Reintam E., Kuht J. 2003. Changes in nutrient uptake and cellular fluid pH of spring barley as affected by soil compaction. *Indian Journal of Plant Physiology*, Special Issue. 552–526.

Reintam E., Kuht J. 2003. Soil compaction effect on barley yield. – XXX CIOSTA-CIGR V Conference proceedings "Management and technology applications to empower agriculture and agro-food systems", Turin, Italy, September 22–24, 2003, Volume 2, 615–622.

Reintam E., Kuht J. 2004a. Soil compaction effect on soil and plants and loosening of compacted soil. – In: (Jones, A.R., Houšková, B., Filippi, N., Michéli, E., Selvaradjou, S.K., Montanarella, L. and Jones, R.J.A. eds.) 2nd European Summer Scool on Soil Survey, Luxembourg: Office for Official Publications of the EC, 223–225.

Reintam E., Kuht J. 2004b. Soil compaction effect on soil, nutrient cycling and weeds in agroecosystem. In: *Integrative approaches towards sustainability in the Baltic Sea region.* (Leal Filho, W., Ubelis, A., eds.), Peter Lang Scientific Publishers, 519–527.

Reintam E., Puust J., Kuht J. 2004. Soil compaction effect on nutrient cycling in agroecosystem. – Proceedings of 4th International Conference on Land Degradation, 12–17 September 2004, Spain: Quaderna Editorial. CD-ROM.

Reintam L. (Ed.) 1970. Soil Regimes and Processes. Transactions EAA, 65. Tartu.

Reintam L. (Ed.) 1971. Biological Productivity and Regimes. Transactions EAA, 75. Tartu.

Reintam L. (Ed.) 1973. Productivity and Properties of Soils. Transactions EAA, 82. Tartu.

Reintam L. (Ed.) 1975. Composition and Characteristics of Soils. Transactions EAA, 100. Tartu.

Reintam L. (Ed.) 1991. Problems of Soil Protection in Estonia. Tallinn.

Reintam L. 1997. Soil Formation. (A. Raukas, A. Teedumäe, Eds.) Geology and Mineral Resources of Estonia. EAP. Tallinn, 298-306.

Reintam L., Leedu E. 1994. Soil Degradation Induced by Oil-shale Mining. (R. J. Rickson, Ed.) Conserving Soil Resources. European Perspectives. CAB International, Cambridge, 36-43.

Reintam, L., Rooma, I. and Kull, A. 2001. Map of Soil Vulnerability and Degradation in Estonia. In: D.E. Stott, R.H. Mohtar and G.C. Steinhardt (eds.) Sustaining the Global Farm. ISCO, USDA-ARS, pp. 1068-1074.

Rooma I. 1994. On the anthropogenic changes in Podzoluvisols. Transactions EAU 179: 13-16.

Roostalu H., Põldma P., Jõudu J. 1999. Application of Fertilizers and Nitrogen Balance in Estonian Soils. Manuscript, EAA, DSA.

Roostalu, H. 2000. About land use in Estonian agriculture. – Transactions EAU, 208:155 – 160.

Roostalu, H., Astover, A., Mõtte, M. 2001. Yield potential and its realization. – Transactions EAU, 212:25–32.

Roostalu, H., Suigussaar, M. 2001. On the developement possibilites of Estonian agriculture. – Transactions EAU, 212:15 – 24.

Roostalu; H. 2000. Quality of arble land in Estonia. – Transactions EAU, 208:147 – 154.

Roots O., Talkop R. (Eds.) 1996. Environmental Monitoring 1995. EME, EIC, Tallinn.

Soovik E., Tomson H., Jõgeva V. 1996. Drainage Preconditions for Sustainable Agriculture in Estonia. Environment and Sustainable Agriculture. EAU, Tartu, 156-159.

Tarasofsky R. G., Krämer R. A. 1998. International Political Commitments and Legal Obligations Concerning Soil Conservation: A Preliminary Examination. Ecological CIEEP.

Van Lynden G.W.J. 1997. Guidelines for the Assessment of Human-Induced Soil Degradation in Central and Eastern Europe (SOVEUR Project). Report 97/08. ISRIC, Wageningen.

Viil, P., Võsa, T. 2004. Agronomical aspects of grain growing technology. – Agronomy 2004. Transactions EAU, 219:31 – 33.

Vipper H., Voor I. 1998. Effect of some basic components of different soil management systems on the characteristics of soil and yield crops. Transactions EAU, 199: 11-17.

Vipper H. 1999. The effect of crop rotations of different agrobiological value on soil qualities and yield of crops. – Transactions EAU, 203:183 – 188.

Vipper H., Lauringson E. 1994. On the technique of direct sowing in the cultivation of winter rye. Transactions EAU, 179: 44 – 46.

Vipper H., Põder I. 1994. Effect of agrotechnology on the quality of the soil, on the biochemical structure and the yield of grops on different tillage conditions. Agronomy 1994 Transactions EAU, 178: 58–63.

World Soil Charter, 1981. 21 FAO Conf/Res., 8/81.