

The management and protection of soil cover: an ecosystem approach

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Abstract. There is need for increased societal awareness of the importance of soil management for varying specific uses and for protection of the environment. The main purpose of the study was to analyze the role of soils in the formation and function of ecosystems, to elucidate the properties and mechanisms which play the main role in plant-soil mutual relationships, and to generalize the pedoecological principles of soil management and protection in conditions of Estonia. The treatment is a departure from the pedocentric viewpoint and is based on an ecosystem approach. The relationships between soil and plant covers are tested quantitatively on the basis of the ecosystems' phytoproductivity and fluxes of organic carbon, and qualitatively on the ground of humus forms and site types. On the basis of personal research and data available in literature, the constraints limiting soil cover functioning, the soil degradation features which occurred in actual time and the measures and activities for prevention of soil degradation are analyzed. Problems connected with biodiversity and soil environment protection ability as they relate to soil cover management and protection are discussed. For sustainable land use and to avoid deterioration of soil properties, the experience of local farmers, scientific research and monitoring of degradation features are needed. The soil cover is protected (or sustainable land use is attained) in circumstances when soil fertility and functioning is maintained adequately for the soil types' characteristics. Soil cover should be considered as a medium through which it is possible to improve the environmental status of the area.

Key words: soil constraints, environmental protection ability of soils, humus status, soil degradation, pedodiversity, ecosystem approach.

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Introduction

The soil cover as an earth stratum and the patterns of soils distribution within it play an essential role in the spreading of arable, forested and semi-natural grasslands areas and, therefore, in regional land use practice (Hellin, 2006; WOCAT, 2007). On forested and semi-natural areas the leading role in the formation and proper functioning of ecosystems belongs to the soils (Reintam, 2004). The mutual causal relationships between natural soil and plant covers, which were transformed under the influence of local meteorological conditions into an equilibrated state, may be characterized (stated) as site specificities (Zanella *et al.*, 2010).

On arable areas, due to soil management and temporally rotating agro-ecosystems, the fluxes of organic matter, cycling of chemical elements and food webs of decomposing material may be quite variable. Besides variability of soil cover properties, the functioning of arable soils may, to a great extent, be influenced by the chosen methods of land management (from low to high input practice) and by the society's scientific-technological capability.

The main tasks of the work were (1) to analyze the functioning regularities of the main local soil types in the composition of different types of ecosystems; (2) to elucidate the optimal levels of soil-plant system functioning by main soil types, (3) to determine possibilities for step-by-step improvement of soil cover productivity and environmental protection ability, and (4) to generalize, in outline form, the pedoecological principles of soil management and protection in the studied area.

Material and Methods

The present work is based on research of mutual relationships between plant associations and soil cover characteristics in conditions of Estonia (Aug & Kokk, 1983; Asi *et al.*, 2004; Kõlli, 2009). The influence of local meteorological conditions is integrated into these relationships as site specifics to *frigid-udic* & *frigid-aquic* pedoclimatic conditions. Our entire method departs from the pedocentric viewpoint, which means that, in natural areas, the composition and functioning of ecosystems are determined first of all by soils.

The functioning of soil is observable in the composition of the ecosystem or in relationships with its components, therefore an ecosystem approach was used in treating the problem. The mutual causal relationships between soil and plant covers (in the soil-plant system) are tested, quantitatively, on the basis of (1) the ecosystems' phytproductivity, (2) fluxes of organic carbon (input & output) in the soil-plant system and, qualitatively, on (3) humus forms (or epipedon types) and forest and grasslands types (Krall *et al.*, 1980; Lõhmus, 2006).

Results and Discussion

Composition and properties of soil cover

Distribution of soils by World Reference Base for Soil Resources (WRB; IUSS..., 2006) in the Estonian soil cover is presented in Table 1. The composition of soil cover, which is observable on easily attainable large scale (1:10,000) soil maps, determines the pattern of natural terrestrial ecosystems, the agricultural activity of the society and the choice of ecologically sound methods for exploitation of land resources (Reintam *et al.*, 2003). The decreasing order of soil groups on forest lands is as follows: *Gleysols*, *Histosols*, *Podzols* and *Cambisols*; on arable lands, *Cambisols*, *Albeluvisols*, *Luvisols*, *Gleysols*, *Histosols* and *Podzols*, and (3) on grasslands, *Gleysols*, *Cambisols*, *Histosols*, *Luvisols* and *Fluvisols* (Kokk, 1995). Most arable lands are attained from forest area with hard work. To avoid disharmony in the endeavour to protect the environment, all aspects of the local soil cover potential should be taken into account.

Each soil type has a certain specific humus status, which depends on soil properties (texture, moisture conditions, calcareousness) and, in arable lands, on soil tillage technology, as well (Table 1). The main quantitative parameters of soil humus status are humus concentration, stocks, and distribution in the soil profile. The regulation of these features is possible mainly in the humus cover or in topsoil. In cultivated areas,

Table 1. Pedological characteristics of soil groups.

Tabel 1. Mullagruppide pedoloogilised karakteristikud.

No Nr	WRB code ¹⁾ or soil by ESC ²⁾ / WRB kood või muld EMK järgi	Area / Pind- ala, %	Ar- able land / Põllu- maa, %	Thick- ness / Tüse- dus, cm	Main texture ³⁾ /Valdav lõimis	Moisture con- ditions / Niiskused ⁸⁾	SOC ⁴⁾ / MOS, Mg ha ⁻¹	SOC bal- ance / MOS bi- lanss, Mg ha ⁻¹ yr ⁻¹	APP ⁵⁾ / AFP, Mg ha ⁻¹	CEC of solum ⁶⁾ / Solumi KNM 10 kmol ha ⁻¹	Base satura- tion of epi- pedon ⁷⁾ / Epipedoni V, %
1.	LP rz sk gl	1.2	19	23	rls/p	dry&fresh&moist	75	2.3	8.0	70	91/96
2.	CM ca skn	6.3	48	34	rls rsl	dry&fresh&moist	86	3.4	8.7	104	93/97
3.	CM mo gln	7.5	52	52	ls	fresh&moist	92	3.6	13.5	169	86/92
4.	LV ct gln	6.4	57	74	sl ls	fresh&moist	106	3.7	14.6	174	75/89
5.	AB gs gsg	9.5	61	92	sl/ls	fresh&moist	67	3.5	13.4	177	29/81
6.	AB ha gln	5.0	28	74	l	dry&fresh&moist	70	3.1	10.2	145	40/81
7.	PZ ha gln	2.5	0	65	l	dry&fresh&moist	46	1.9	7.4	61	19/-
8.	GL mo cc eu	14.5	20	43	ls	wet (epigleyic)	122	3.2	13.2	126	78/85
9.	GL lv dyp	8.1	19	57	sl ls	wet (epigleyic)	125	3.1	13.0	194	69/78
10.	GL sd um dy	5.1	7	72	l-ls	wet (epigleyic)	90	2.6	7.2	156	34/68
11.	GL his	4.7	14	47	t ₂₋₃ /l-s	wet (peaty)	191	2.5	6.5	135	65/75
12.	PZ hif	1.6	<1	76	t ₁ /l	wet (peaty)	114	1.8	3.7	166	18/-
13.	Eroded soils	1.2	72	54	l-ls	dry&fresh	38	1.7	n.d.	n.d.	n.d.
14.	Deluvial soils	0.9	69	80	sl-ls	fresh&moist	105	3.0	n.d.	n.d.	n.d.
15.	FL eu glp his	0.9	15	36	l-ls	moist&wet&peaty	121	2.9	n.d.	n.d.	n.d.
16.	Coastal soils	0.7	<1	13	l-s	moist&wet&peaty	56	0.8	n.d.	n.d.	n.d.
17.	HS sa eu	13.8	15	50	t ₃₋₂	wet, peat	333	2.2	6.7	170	60/75
18.	HS fv	0.5	1	50	t ₂₋₃	wet, peat	206	2.4	n.d.	n.d.	n.d.
19.	HS dy	3.7	1	50	t ₁₋₂	wet, peat	210	1.8	4.1	75	40/-
20.	HS fi	5.7	<0.5	50	t ₁	wet, peat	139	1.2	1.9	30	15/-
21.	RG pr sp	0.2	0	25	l-s	fresh&moist&wet	43	0.3	n.d.	n.d.	n.d.

1) WRB reference soils: LP – Leptosols, CM – Cambisols, LV – Luvisols, AB – Albeluvisols, PZ – Podzols, GL – Gleysols, FL – Fluvisols, HS – Histosols, RG – Regosols;

WRB qualifiers: rz – rendzic, sk – skeletic (skn – endoskeletal), gl – gleyic (gln – endogleyic, glp – epigleyic), ca – calcaric, mo – mollic, ct – cutanic, gs – glossic (gsg – endogleyic), ha – haplic, cc – calcic, eu – eutric, lv – luvis, dy – dystic (dyp – epidystic), sd – spodic, um – umbric, his – sapri-histic, hif – fibrihistic, sa – sapric, fv – fluvic, fi – fibric, pr – protic, sp – spolic;

2) ESC – Estonian Soil Classification;

3) r – gravelly, ls – loam, p – limestone, sl – loamy sand, l – sand, s – clay, t – peat (accordingly 3 – well, 2 – moderately and 1 – slightly decomposed);

4) SOC – soil organic carbon;

5) APP – annual phytoproductivity, n.d. – not determined;

6) CEC – cation exchange capacity;

7) first number in forest/second in arable soil.

1) Mullakoodid WRB järgi – kaks suurt tähte annavad kokku referentsmulla nimetuse, sellele järgnev tähepaar (või kolmik) näitab referentsmulla alajaotusi;

2) WRB muldade vasted EMK (Eesti muldade klassifikatsiooni) järgi on mullagrupi numbrite kaupa järgmised: 1 – paepealsed, 2 – rähksed, 3 – leostunud, 4 – leetjad, 5 – kahkjad, 6 – leetunud, 7 – leede-, 8 – rähksed, leostunud ja küllastunud glei-, 9 – leetjad ja küllastumata glei-, 10 – leetunud ja kahkjad glei-, 11 – turvastunud glei-, 12 – turvastunud leede-glei-, 13 – erodeeritud, 14 – deluviaalsed, 15 – lammi-, 16 – ranniku, 17 – madalsoo-, 18 – lammi-madalsoo-, 19 – siirdesoo-, 20 – raba- ja 21 – rikutud või vähearenenud mullad;

3) Mulla lõimised: r – rähk, ls – liivsavi, p – paas, sl – saviliiv, l – liiv, s – savi ja t – turvas (vastavalt 3 – hästi, 2 – keskmiselt ja 1 – halvasti lagununud);

4) MOS – mulla orgaaniline süsinik;

5) AFP – aastafütoproduktiivsus (n.d. – ei määratud);

6) Solumi kationide neelamismahutavus (KNM);

7) Epipedoni küllastusaste (V) protsentides: esimene arv metsades, teine põllumullas;

8) Niiskused: dry – kuiv, fresh – värske, moist – niiske, wet – märg, peaty – turvastunud ja peat – turvas.

Table 2. Ecological characteristics of soil groups.
Tabel 2. Mullagruppide ökoloogilised karakteristikud.

No Nr	WRB code or soils by ESC ¹⁾ <i>WRB kood või muld EMK järgi</i>	Forest ²⁾ <i>Metsa-</i>	Grassland ³⁾ <i>Rohumaa-</i>	Forest ⁴⁾ <i>Metsa-</i>	Cropland ⁵⁾ <i>Põllumaa</i>	Quality class of forest ⁶⁾ <i>Metsa boniteet</i>	Quality of cropland ⁷⁾ <i>Põllumaa boniteet</i>	EPA ⁸⁾ / KHV	
		site type <i>kasvukohatüüp</i>		humus forms <i>huumusvorm</i>				credits <i>punktid</i>	class <i>klass</i>
1.	LP rz sk gl	ll kl	Lok Lon	ml1(k v n)	Avk Amr	IV-V	29/26	3.6	III-V
2.	CM ca skn	kl lul	Lok Lon	ml1(k v n)	Avk Amr	II-IV	50/47	6.6	II-III
3.	CM mo gln	sl nd	Aak Aan	ml2(k v n)	Amn	I-III	58/56	10.1	I-II
4.	LV ct gln	sl nd	Aak Aan	md-ml (v n)	Ahl	I ^a -II	56/54	11.2	I-II
5.	AB gs gsg	jk jk-ms	Pak Pan	md(v n)	Ahl	I ^a -II	53/51	12.1	I-II
6.	AB ha gln	jk ms	Pak Pan	md(k v n)	Ahf Avh	I-II	38/34	8.2	I-III
7.	PZ ha gln	ph sm kn ms	Nök Nön	mo(k v n)	Avh Ahf	II-IV	-/-	5.2	III-IV
8.	GL mo cc eu	sj an os	Sor	ml2(m)	Hhe	II-IV	52/28	7.9	II
9.	GL lv dyp	an os tr	Sor	md-ml (m)	Hhm	II-IV	49/27	9.6	I-II
10.	GL sd um dy	kr	Sov	md-mo (m)	Hho	III-IV	46/25	9.3	II
11.	GL his	os tr	Sor	ml(t)	Hhe Hho	IV-V	41/22	5.3	III-IV
12.	PZ hif	sn kr	Sov	mo(t)	Hho	V-V ^a	-/-	4.4	IV-V
13.	Eroded soils	sl jk ph	Der Sü	ml md (k v)	Av Am Ah	I-III	32/32	7.2	I-III
14.	Deluvial soils	jk nd an	Del	md(k v n)	Ahd Hhd	I-III	45/40	10.8	I-II
15.	FL eu glp hi	nd sj	Lem Lk Lt	md(k v n)	Hha Hta	II-III	48/30	8.6	II-III
16.	Coastal soils	sj	Ran Ras	ml md (m t)	Hhp Hta	III-V	17/8	5.5	III-IV
17.	HS sa eu	mds	Mav Mar	tue	Hte	II-IV	52/19	8.0	II-III
18.	HS fv	ld mds	Ls	tue	Hta	II-IV	55/20	8.1	II-III
19.	HS dy	ss	Sip Sir	tum	Htm	V-V ^a	32/12	4.8	III-IV
20.	HS fi	rb	Rbn Rbk	tuo	Hto	V ^a	21/8	2.7	V
21.	RG pr sp	-	Avk Krp	proto	proto	-	-/-	1.8	(V)

1) see table 1;

2) ll – Arcostaphylos-alvar, kl – Calamagrostis-alvar, lul – Sesleria-alvar, sl – Hepatica, nd – Aegopodium, jk – Oxalis, ms – Myrtilus, ph – Rhodococcum, sm – Cladonia, kn – Calluna, sj – Dryopteris, an – Filipendula, os – Equisetum, tr – Carex, kr – Polytrichum, sn – Vaccinium uliginosum, mds – Alder-birch, ld – Alder, ss – transitional bog, rb – raised bog;

3) grasslands: Lok – dry alvar, Lon – moist alvar, Aak – dry typical, Aan – moist typical, Pak – dry heathy, Pan – moist heathy, Nök – dry heath, Nön – moist heath, Sor – rich paludified, Sov – poor paludified, Der – eroded, Sü – hilly, Del – deluvial, Lem – wet floodplain, Lk – wet tall-grass floodplain, Lt – carex floodplain, Ran – typical coastal, Ras – paludified coastal, Mav – poor fen, Mar – rich fen, Ls – floodplain fens, Sip – typical transitional, Sir – herbaceous transitional, Rbn – heath bog, Rbk – high bog, Avk – open communities, Krp – outcrops;

4) ml1 – calci-mull, ml2 – forest mull, md-ml – moder-mull, md – moder, mo – mor, md-mo – moder-mor, tu – peat (e – eu-, m – meso- and o – oligotrophic) and indicators of moisture conditions (in parentheses): k – dry, v – fresh, n – moist, m – wet and t – peaty;

5) Avk – calcareous low humous, Amr – skeleti-calcaric mild humous, Amn – neutral mild humous, Ahl – eluvic moder humous, Ahf – fulvic moder humous, Avh – acid low humous, Hh – row-humous (or organo-mineral) where e – eu-, m – meso- and o – oligotrophic, Av, Am and Ah are accordingly low, mild and moder humous, Ahd – deluvial moder humous, Hhd – deluvial raw-humous, Hha – al-luvial raw-humous, Hhp – primitive raw-humous, Ht – peats (Hta – alluvial, Hte – eutrophic, Htm – mixotrophic, Hto – ombrotrophic);

6) I^a – the highest and V^a the lowest quality;

7) with/without artificial drainage;

8) classes of environment protective ability: I – good, II – relatively good, III – satisfactory, IV – relatively weak and V – weak.

1) vt. tabel 1;

2) ll – leesikaloo, kl – kastikuloo, lul – lubikaloo, sl – sinilille, nd – naadi, jk – jänesekapsa, ms – mustika, ph – pohla, sm – sambliku, kn – kanarbiku, sj – sõnajala, an – angervaksa, os – osja, tr – tarna, kr – karusambla, sn – sinika, mds – madaloo, ld – lodu, ss – siirdesoo, rb – raba;

3) Rohumaad: Lok – kuivad loo-, Lon – niisked loo-, Aak – kuivad pärisaru-, Aan – niisked pärisaru-, Pak – kuivad palu-, Pan – niisked palu-, Nök – kuivad nõmme-, Nön – niisked nõmme-, Sor – liigirikkkad soostunud, Sov – liigivaesed soostunud, Der – erodeeritud, Sü – sürja-, Del – deluviaalsed, Lem – märjad aasa-, Lk – suurkõrreliste lammi-, Lt – suurtarna-, Ran – päris-ranna-, Ras – soostunud ranna-, Mav – liigivaesed madaloo-, Mar – liigirikkkad madaloo-, Ls – lammisoo-, Sip – päris-siirdesoo-, Sir – roht-

siirdesoo-, Rbn – nõmmraba, Rbk – kõrgraba, Avk – avakooslused, Krp – karjäärde paljandid;
 4) ml1 – kaltsi-mull, ml2 – metsa-mull, md-ml – moder-mull, md – moder, mo – moor, md-mo – moder-moor, tu – turvas (e – eu-, m – meso- and o – oligotroofne) niiskuselude näitajad (sulgudes): k – kuiv, v – värske, n – niiske, m – märg ja t – turvastunud;
 5) Avk – vähehuumuslik karbonaatne, Amr – pehmeuumuslik rähkne, Amn – pehmeuumuslik neutraalne, Ahl – keskmisehuumuslik leetjas, Ahf – keskmisehuumuslik fulvaatne, Avh – vähehuumuslik happeline, Hh – toorhuumuslik (või organo-mineraalne) kus e – eu-, m – meso- ja o – oligotroofne, Av, Am ja Ah on vastavalt vähe-, pehme- ja keskmisehuumuslikud, Ahd – keskmisehuumuslik deluviaalne, Hhd – toorhuumuslik deluviaalne, Hha – toorhuumuslik alluviaalne, Hhp – toorhuumuslik primitiivne, Ht – turbad (Hta – alluviaalne, Hte – eutroofne, Htm – mesotroofne, Hto – oligotroofne);
 6) I^a – kõrgeim ja V^a madalaim boniteet;
 7) kuivendatud/kuivendamata;
 8) KHV – keskkonnahoiuvõime: I – hea, II – võrdlemisi hea, III – rahuldav, IV – võrdlemisi nõrk ja V – nõrk.

the tools may include crop rotation, tillage methods, liming, water regime regulation, soil loosening, among others.

The quality of soil organic matter is determined by humus forms (epipedon types), which are characterized by the fabric of organic matter contained in topsoil horizons and by the composition of soil organic matter (particular, real humus, inert substance) (Table 2).

Constraints of soil cover

For better management of local soil cover, the particular soils' capabilities as well as the features and causes of the soils' weaknesses or constraints should be taken into account (Kõlli *et al.*, 2006). The constraints of soil are features or circumstances (deficiency, shortcoming, disability) which hinder (limit, prevent) the optimal functioning of soil and prevent its reaching the productivity expected based on the bioclimatic region. The main constraints of soils, which decrease soil productivity and functioning activity in Estonian conditions are water-logging (high ground water level, perched water), scarcity of organic carbon in topsoil, extremely coarse (skeletal) soil texture, water (snow melt, wind) erosion, flooding (inundation, ponding) and drought hazards. Other constraints may be the presence of lithic, strongly podzolized (or acidified) and compacted soil layers in the rooting zone. Two additional constraints related to arable soils are (1) a low sum of efficient temperatures (as Estonian soils are rather closer to cryic than temperate conditions; IIASA, 2002) and (2) very high variability of contrasting soil types contours. The last hinders to use management practice suitable for soil.

Soil degradation features

Soils' degradation features and their causes are widely variegated and depend on soil properties, local ecological conditions, land use, external influences and societal activity (Reintam *et al.*, 2001). According to van Lynden (1997) soil degradation is deterioration of soil quality, i.e. the partial or entire loss of one or more potential functions of the soil. We have grouped soil degradation features (which occurred in actual time) into three groups, as follows:

- (1) Relatively easily identified, well-known features: diffuse and/or point source pollution and contamination (including radioactivity) of soils, compaction of soils, water, wind and tillage erosion, soil acidification, water-logging and permanent

anaerobic conditions (among them formerly drained hydromorphic soils), excessive non-controllable weeding, alkalinization of soils by flying ash, blockage of natural drainage by road construction and building, the formation of miscellaneous soils on mined areas, and dumping of mining residues from chemical stations.

- (2) Degradations connected with soil type: formation of ironstone hardpan and humus-illuvial horizons on strongly gleyed and peaty *Podzols*; flooding of *Fluvisols* on coastal areas and river valleys; accelerated mineralization of peat on drained shallow *Histosols*; formation of thapto-humic horizon on *Colluvial* soils, and strong podzolization (with acidification) of *Albeluvisols* and *Podzols*.
- (3) Ecologically explained soil degradation features: destruction of soil type-specific (normal) soil functioning, degeneration of soil type-specific biological activity, depletion of soils from nutrition elements under the critical level and worsening of its humus status, and the presence of a new anomaly (deficiency or excess) in trace elements contents.

In the course of soil degradation the soil constraints are increased and become more clearly visible.

Soil protection

The measures to prevent soil degradation are as numerous and various as the factors which cause the problem. In general, the activities for prevention of soil degradation are the following:

- (1) Enhancement of public awareness concerning soil protection: creating soil survey institutions for information sharing and dissemination; integrating the extension services with research institutions; investing in new technologies suitable for local soil conditions; giving substantive attention to soil properties and environmental protection functions in the planning of landscapes.
- (2) Introduction of sound measures for the sustainable use and protection of soils: propagation of good local agricultural practice; respecting the knowledge and practice of local communities; organizing ecological expertise of projects concerning soils.
- (3) Systematic monitoring of soils with information distribution: making soil mapping materials available for land users and application them for land management.
- (4) State-supported programs for liming of arable soils, for restoration of contaminated soils and for reconstruction of drained areas, and restoring vegetation surrounding the buildings, roads and areas vulnerable to degradation.
- (5) Enforcement of legislation for protecting fertile soils (reduce the sealing of soils with a high agronomic quality).

Therefore, for prevention and mitigation of degradation processes, the ecologically proper land utilization, soil remediation (liming, fertilization, drainage, input of additional organic matter), balanced nutrition elements cycling and locally suitable technology for conservation agriculture (minimum tillage, mulching) should be used.

The best results in soil cover protection may be reached by knowledge-based and expedient methodology in the management of ecosystems. Of decisive importance in the arrangement of sustainable land use is the matching of soil cover with suitable plant cover on natural areas, and with crops on arable lands (Table 2). In management of arable soils the tools of conservation agriculture (equilibrated and exactly-

timed fertilization, establishment of suitable-for-soil crop rotations, consideration of the soil's humus status and biological activity, etc.) should be used (WASWC, 2008).

Environment protection ability of soils

The environmental protection ability (EPA) of soil should be considered in the evaluation of local soil cover (Kõlli *et al.*, 2008). The EPA of soils is an integrated capability of the soil cover to stabilize the functioning of the soil's ecosystem in the discharging of environmentally harmful fluxes of substances into the soil. The influence of soil cover on the environmental conditions of an area depends greatly on soil type peculiarities. Soils with a low EPA are highly vulnerable to degradation, but those with high EPA are more resistant to negative influences and may be used more intensively for agricultural purposes. The biological aspect of the EPA of the soil is reflected in the soil's capability to form productive plant association with sufficient litter inflow into the soil, thus facilitating the process of mineralization and humification and thereby sustaining the soil's organisms.

For evaluation of soils' EPA the soil humus status, texture, specific surface area, cation exchange capacity, calcareousness, thickness, biological activity and fabric of epipedon were used (Table 2). If the EPA of the epipedon is determined first by the content and quality of soil organic matter, then the EPA of the metric soil layer can be calculated mainly by soil particle size composition and the presence of coarse soil material (Kõlli *et al.*, 2004). The soil management strategies, which lead to higher soil productivity, also enhance the soil's ability to protect the environment.

Relationships of pedo- and biodiversity

Biodiversity of a particular nondisturbed natural area is determined by soil cover. This thesis has been successfully verified by forest management practice which, for more than a century, was based on the forest site types theory (Lõhmus, 2006). According to the theory, the soil productivity and quality were not determined directly, but via the plant cover (especially after ground vegetation). But the local soil cover diversity (pedodiversity) is the reflection of the area's geology or its geodiversity. So, if the pedodiversity formed via soil processes is the heritage of geodiversity, then the biodiversity of the plant cover is the heritage of local pedodiversity. Biodiversity induced by pedodiversity is observable in low input soil management. In high input agriculture the hereditary biodiversity is overshadowed by anthropogenic impact. The disharmonies between pedodiversity and biodiversity should be overcome by pedo-ecologically justified management.

Strategy of land use

The composition of soil cover, its productivity, biological activity and its influence on the environmental status of the area are site specific and globally, widely divergent (IIASA, 2002). By soil thematic strategy for soil protection (CEC, 2006), the soil cover composition in every pedoclimatic region has certain individual properties peculiar only to this region. This emphasizes the importance of local know-how on land use, land tillage, fertilizer load, etc. Therefore, we must maintain the valuable experience acquired by our ancestors, but we are obligated to add to this present day scientific advantages. Estonian soil cover has sufficient soils with high environmental rating providing a good possibility for developing intensively managed sustainable agriculture.

During the previous century, in typical Estonian landscapes with dispersed settlements around villages, the best soil varieties for agriculture were chosen for their texture, moisture conditions and fertility. Optimal land use has been achieved in most of Estonia, but certain corrections are needed (re-forestation of low fertile fields, amelioration of *Gleysols* etc.) throughout the country.

Soil cover should be considered as a medium through which it is possible to improve the environmental status of the area. Soils with high EPA are more resistant to negative influences, but those with a low EPA are highly vulnerable to degradation. One tool for soil cover protection is conservation agriculture, which is based on equilibrated and exactly timed fertilization, establishment of suitable-for-soil crop rotations, and taking into consideration of soil's humus status and biological activity.

Conclusions

The management of soil resources should be arranged in accordance with need, awareness and the scientific-technological level of society. For successful implementation of sustainable land use and for protection of soils against degradation, the long-lived experience of local farmers, plus current scientific research about soils and causality of their degradation features (monitoring) are needed.

The best results in soil cover protection may be reached by an ecologically sound management of ecosystems. The soil cover is protected (or sustainable land use is attained) in circumstances when soil fertility and functioning is maintained according to the soil type characteristics.

The philosophy of soil conservation should be much more refined and scientifically based on local ecological conditions, and sustainable soil use should be introduced on the detailed taxonomic or soil mapping unit level. It is feasible, based on easily attainable materials of large-scale soil mapping and respective (adequate) know-how.

Soil cover is a medium through which the environmental status of an area can be improved. Therefore the role and needs of soil must be taken into account in all environmental and agriculture projects considered for subsidization. This is possible when the society's awareness of soils is at a high level and in conditions where soils are regularly monitored.

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Muldkatte majandamine ja kaitse: ökosüsteemne käsitlus

Raimo Kõlli ja Arno Kanal

Kokkuvõte

Põhiliseks looduslike ökosüsteemide koostise kujunemise determineerijaks ja talitlemise liikumapanevaks jõuks on muldkate. Nii ökosüsteemi liigiline koostis, aine- ja energia maht kui ka toitumisahelad on arenenud ja funktsioneerivad tihedais vastastikustes seostes mullaga, kusjuures selle tasakaaluline seisund ja talitlemise intensiivsuse tase määratakse ära vastava mulla keemilis-mineraalse potentsiaali ja omadustega. Kultuuristatud ökosüsteemid on alati suuremal või vähemal määral (sõltuvalt juurdeantud sisenditest) mõjutatud inimese majanduslikust tegevusest, mille tõttu mulla potentsiaalne mõju väljendub ebaselgemalt.

Käesolevas töös analüüsitakse muldade rolli ökosüsteemide väljakujunemises ja talitlemisel ning selgitatakse välja need omadused ja mehhanismid, millised on määrava tähtsusega Eesti tingimustes. Taolised üldistused on suureks abiks muldade ökoloogiliselt õige majandamise ja kaitse kujundamisel. Töös käsitletakse probleemi ökosüsteemi tasemelt, kasutades sealjuures muldkeskse lähenemise printsiipi.

Muld- ja taimkatete vastastikuste seoste kvantitatiivseteks näitajateks antud töös on ökosüsteemide aastafütoproduktiivsus, orgaanilise süsiniku aastabilanss, muldkatete agro-füüsikalised omadused ja huumusseisund ning muldade ja/või metsa produktiivsust näitav boniteet, kvalitatiivseteks aga – moodustunud huumusvormid ning mulla-, metsakasvukoha- ja rohumaatüübid.

Kasutades autori poolt tehtud ja teaduslikes artiklites esinevate uurimuste andmeid üldistatakse muldade omadustega seotud puuded, milliste tõttu väheneb muldkatte produktiivsus või on takistatud regioonile omane talitlemise tase. Klassifitseerituna esitatakse käesoleval ajal toimivad muldade degradatsiooni nähted ning võtted ja vahendid, mis aitavad neid leevendada või hoopiski vältida. Töös leiab käsitlust veel ka muldade kasutamise ja kaitsega seotud muldade- ja taimkatete bioloogiline mitmekesisus ja muldade keskkonda kaitsev talitlemine.

Järeldatakse, et ökoloogiliselt jätkusuuteliseks maakasutuseks ja muldade degradatsiooni vältimiseks (leevendamiseks) vajatakse nii kohalike maakasutajate aastakümnete pikkusi kogemusi, teaduslikke uurimusi kui ka muldade seisundi süstemaatilist seiret (monitooringut). Leitakse, et mullaomadusi arvestavat muldade majandamist saaks korraldada paremini st. otseses vastavuses ühiskonna vajaduste ja teaduslik tehnilise tasemega. Muldkate on sisuliselt hästi kaitstud juhul kui muldade funktsioneerimine ja produktiivsus on vastavuses mullatüübi omaduste ja keemilis-mineraalse potentsiaaliga. Muldkatete tuleks käsitleda kui looduslikku moodustist, mille kaudu on võimalik parandada või reguleerida piirkonna üldist keskkonnaseisundit.

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