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MULD PAEKIVIL – EESTI AASTA 2015 MULD

SOIL ON LIMESTONE – YEAR 2015 SOIL OF ESTONIA

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ABSTRACT. By Estonian Soil Sciences Society for the year 2015 soil of Estonia the limestone rendzina was elected. After WRB these soils embrace different kind of Rendzic Lithic Leptosols. The area of limestone rendzina forms only 1.2% from whole Estonian soil cover. In overview on Estonian year 2015 soils' morphology, genesis, classification, humus status and different properties (chemical, physical, hydro-physical) are treated in detail. The functioning and properties of limestone rendzinas are treated by Estonian Soil Classification on soil species (identified by soil genesis) and soil varieties (divided on the basis of soil texture) levels. Besides that the limestone rendzinas' productivity, environment protection ability in dependence upon soil functioning and properties, usage in agriculture and forestry, and distribution in Estonia are analysed as well.

Sissejuhatus

Eesti mullateaduse selts valis aasta 2015 mullaks paepealse mulla. Nende muldade erilise tähelepanu alla võtmine ei ole seotud nende olulisusega pindala (moodustavad 1,2% Eesti muldkatte kogupindalast) ega produktiivsuse (mis on alla keskmist) poolest. Ennekõike on need Ordoviitsiumi ja Siluri kivistunud karbonaatsetel lademetel kujunenud mullad pälvinud esiletõstmise omapärase ülesehituse, teistest erinevate omaduste ja ökoloogia poolest. Paepealsed mullad on loopealsete ökosüsteemide alusmullaks ja esindavad kujukalt põhjamaiselt karme mullaolusid.

Eesti paepealseid muldi käsitlevate publikatsioonide hulk on suhteliselt rikkalik ja mitmekülgne. Üheks põhjalikumaks ülevaateks nendest muldadest on *Eesti Põllumajandusprojekti* (EPP) peamullateadlase I. Rooma poolt Eesti Loodusuurijate Seltsi aastaraamatu 64. köites avaldatud artikkel (Rooma, 1976). Huvi paepealsete muldade vastu leiab juba eelmise sajandi kolmekümnendatest aastatest (Nõmmik, 1927). Varasematest töödest on eriti tähelepanuväärsed A. Lillema arutelud paepealsete muldade klassifitseerimisest, nimetuste kujunemisest ja ökoloogiast (Lillema, 1958). Mullateadlased on pidanud tähtsaks botaanikute G. Vilbaste, T. Lippmaa, L. Laasimeri jt ning metsateadlaste E. Kaare, A. Karu, E. Lõhmuse, R. Sepa jt teaduslikke uurimusi paepealsete muldade ja taimkatte vastastikuste suhete kohta (Sepp, 1959, 1960, 1962; Laasimer, 1965; Rooma, 1976; Reintam, Rooma, 2001; Lõhmus, 2006). Paljude kirjanduslike allikate järgi on selgunud paepealsete muldade arengu regionaalsed eripärasused ja sellest johtuvad klassifitseerimise põhimõtted (Lillema, 1958; Sepp, 1960; Rooma, 1976; Kask, 1996; Reintam, Rooma, 2001). Harivad on eri aspektidest lähtuvad ülevaateartiklid (Nõmmik, 1927; Lillema, 1962; Rooma, Sepp, 1972; Rooma, 1976; Reintam, Rooma, 2001). Paepealsetele muldadele on rajatud mitme otstarbega püsi-uurimisalasid, mis on võimaldanud selgitada mulla omadustest tulenevaid mõjusid ökosüsteemi kui terviku arengule (Sepp, 1959, 1960; Zobel, 1984; Kokk, 1987). Heal tasemel on uuritud nii nende huumuse fraktsioonilist koostist (Rooma 1976; Reintam 1975, 1982) kui ka nende aluseks oleva paekivi mineraalset koostist (Oja, 1982). Muldkatte olulisust maastike arengule on oma monograafias maastiku tüüpide (paigastike) ja rajoonide kaudu käsitlenud I. Arold (2005). Suurt huvi on pakkunud muidugi ka paepealsete alade kasutamine (Kaar, 1959; Laasimer, 1975; Krall jt, 1980).

Tingituna väikesest muldkatte tüsedusest vajavad paepealsed mullad kestlikkuse huvidest lähtuvalt ökoloogiliselt põhjendatud (otstarbekohast) kasutusviisi. Selle toimimise eeldus on aga igakülgne mulla omaduste ja talitlemise seaduspärasuste tundmine. Kahjuks on aga EPP seeriaväljaande köited *Eesti NSV mullastik arvudes* (EMA), kui ühed kõige olulisemad andmeallikad Eesti muldade kohta, vähese levikuga ja seega asjaosalistele raskesti kättesaadavad. Seoses paepealse mulla valimisega aasta 2015 mullaks on käesoleva töö eesmärk teha asjakohane ülevaade paepealsete muldade ülesehitusest, omadustest ja levikust Eestis kogutud ja talletatud vastavasisulise uurimismaterjali põhjal. See on ühtlasi järg aasta 2014 mulla käsitlusele (Kõlli, 2014).

Materjal ja metoodika

Põhiline töös kasutatav andmestik pärineb aastatel 1955–1990 tulemuslikult tegutsenud EPP mullastiku uurimise osakonna (MUO) poolt läbiviidud välitöödest ja põllumajandusministeeriumi toel publitseeritud väliuurimise- ja laboratoorsete analüüside statistiliselt läbitöötatud andmestiku väljaannetest (Kokk, Rooma, 1974, 1978; Kokk, 1983, 1987; Maa-ameti geoportaal, 2014). Lisaks sellele on kättesaadavad ka muudes teaduslikes väljaannetes publitseeritud materjalid (Sepp, 1959, 1960, 1962; Rooma, Sepp, 1972; Reintam, 1975, 1982; Rooma, 1976 jt) ja autorite poolt tehtud üldistused, mis näitavad paepealsete muldade omadusi võrreldes teiste Eesti muldadega (Kõlli, 1991a, 1991b; EMDK, 2008).

Paepealseid muldi käsitletakse antud töös liigi ja erimi tasemel. Mullaliikide üle arutlemiseks on vajalik tunda muldade morfoloogia aluseks olevaid mullahorisonte, nende tunnuseid ja tähistusi ning olla kursis mullaliikide ja koodide nimestikuga (Maa-amet, 2001; Astover jt, 2013). Mullaprofiilide valemite koostamisel kasutatud horisontide tähistused on: O – kõdu-, A – huumus-, AT – toorhuumuslik, T – turba-, B – sisseuhte-, C – lähtekivimi, G – glei- ja R – aluskivimi horisondid. Lisaks nendele on kasutatud veel ka järgmisi täiendeid: BC ja CG – liit- ehk üleminekuhorisondid, g – gleistunud ja 3 (alaindeksina) – hästi lagunenud turvasmuld.

Mullaerimite üle arutlemisel oleks vaja tunda mullapeenese ja -korese nimetusi, lühendeid ja mõõtmeid ning teada koresesisalduse astmeid. Antud töös kasutatud korese liigid on: r – rähk, v – veeris, kr – kruus, kb – klibu ja p – paas. Mullapeenese lõimiste puhul eelistatakse mullastiku kaartidel ja tabelites kasutada sõnade asemel vastavaid lühendeid, millisteks antud töös on: l – liiv, sl – saviliiv, ls_1 – kerge liivsavi, ls_2 – keskmine liivsavi, ls – liivsavi (st ls_1-ls_2) ja s – savi. Mullapeenese lõimise alusel eristatakse iga mullaliigi piires üks või mitu mullaerimit. Näiteks Kh" ls/p, kus Kh" näitab, et tegemist on õhukese paepealse mulla(liigi)ga, mille lõimis(erim) on liivsavi pael või Kh'g r_3ls_2/p, kus on tegemist gleistunud väga õhukese paepealse mullaga, mille lõimiseks on tugevasti rähkne keskmine liivsavi pael (Astover jt, 2013).

Valdav osa tabelites toodud paepealseid muldi iseloomustavaid karakteristikuid on antud üldistatud vahemikena (M±SD) ehk aritmeetiline keskmine (M) pluss/miinus ühekordne standardhälve (SD).

Rahvusvahelise suhtlemise otstarbel on kohalikud mullanimed konverteeritud *World Reference Base for Soil Resources* (WRB) nimedeks, kusjuures kohalik väliuurimistööde juhend on korreleeritud FAO väliuurimise juhendiga (FAO, 2006; IUSS, 2014). Kui Eesti mullaliikide konverteerimisel WRB süsteemi on piisavalt võimalusi hea vastavuse saavutamiseks, siis mullaerimite puhul on see komplitseeritum suurte põhimõtteliste erinevuste tõttu mullapeenese, eriti aga mullakorese klassifitseerimisel osakeste läbimõõdu alusel.

Eesti paepealseid muldi iseloomustav andmestik

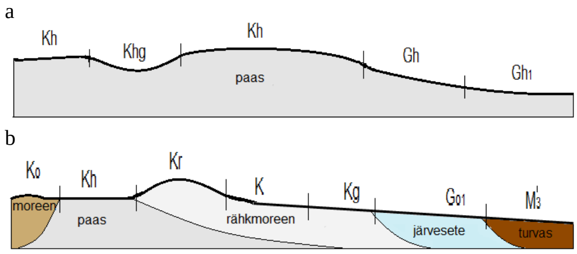
Jaotus liikideks. Paepealsed mullad, kui õhukesed (<30 cm) massiivsel paekivil lasuvad huumus- ja lubjarikkad (s.o karbonaatsed) mullad, on moodustunud mandrijää- või selle geoloogiliselt läbitöötatud setetest, lokaalsest paemurendist või nende koosmõjul (Fotod 1, 2). Paepealsed mullad "keevad" ehk "kihisevad" 10% HCl vesilahuse toimel (st sisaldavad $CaCO_3$ ja/või $MgCO_3$ tükikesi) 30 cm sügavusest kõrgemal. Eesti muldade nimestikus eristatakse seitse paepealsete muldade liiki (liiginimi ja kood):

Väga õhuke paepealne muld	Kh'
Õhuke paepealne muld	Kh"
Gleistunud väga õhuke paepealne muld	Kh'g
Gleistunud õhuke paepealne muld	Kh"g
Väga õhuke paepealne gleimuld	Gh'
Õhuke paepealne gleimuld	Gh"
Turvastunud paepealne muld	Gh1

Igal mullakoodi tähel ja märgil on oma kindel teatud olulist omadust või tunnust kajastav tähendus: K – karbonaatne, h – huumusrikas, ' – väga õhuke (A või AT <10 cm), " – õhuke (A või AT 10–30 cm), g – gleistunud st ajutiselt liigniiske ehk niiske, G – glei- st alaliselt liigniiske ehk märg, 1 – profiilis esineb 10–30 cm paksune valdaval osal vegetatsiooniperioodist tugevasti liigniiske T-horisont.

Mullaliigi koode kasutatakse peamiselt mullastiku kaartidel, kuid ka tabelites ja erialastes tekstides ruumi kokkuhoiu mõttes. Juhul kui mullaliigi sügavuste (väga õhuke ja õhuke) eristamine pole vajalik, kasutatakse koode Kh, Khg ja Gh, kus vastavalt Kh' ja Kh", Kh'g ja Kh"g ning Gh' ja Gh" on kokku võetud.

Veeolud. Paepealsete muldade leviku seost veeoludega (alates aeromorfsetest kuni alaliselt liigniiskete (hüdromorfsete) turvastunud muldadeni) näitab hüdrokateena (joonis 1a). Kompleks-kateenal on peale loodude reljeefist tingitud veeolude muutumise kajastatud veel ka lähtekivimist tingitud mullaliikide leviku seaduspärasused (joonis 1b).



Joonis 1. Kateenad paepealsete muldadega (a – kateena 1 (hüdrokateena), iseloomustab paepealsete muldade leviku seost loodude reljeefist tingitud veeolude muutustega; b – kateena 2 on näide paepealsete muldade levikust koos omadustelt lähedaste mullaliikidega; mullad: Kr – koreserikas rähkmuld, Kog – gleistunud leostunud muld, Go – leostunud gleimuld, M'_3 – väga õhuke hästi lagunenud madalsoo-turvasmuld)
Figure 1. *Catena with limestone rendzina (a – Catena 1 characterizes the dependence of limestone rendzinas distribution on changing moisture conditions of alvars; b – Catena 2 is an example on distribution of limestone rendzinas in relationship with other genetically close soil species; soils*: Kr – *pebble rich rendzina*, Kog – *gleyed leached soil,* Go – *leached gley soil*, M'_3 – *well decomposed very shallow fen soil)*

Vähese vettsiduva mullapeenese (liivad, tolmud ja savid) varu tõttu kannatab õhurikaste (aeromorfsete) paepealsete muldade taimestik sageli põua all ehk tegemist on põuakartlike muldadega. Mida õhem ja räharikkam on huumushorisont, seda põuakartlikum on muld. Samas on osa paepealsetest muldadest ajutiselt (kevaditi ja sügiseti ühel nädalal) või pikemaajaliselt liigniisked. Pikemaajalisele liigniiskusele viitab gleistumise tunnuste (roostetäpid, mullapeenese rohekashall toon, kollaka värvusega pealt murenenud paekivi tükid) esinemine ja orgaanilise aine akumuleerumine toorhuumuse või turba kujul. Gleistumise tunnused on selgemalt välja kujunenud alaliselt liigniisketes (märgades) glei- (Gh) ja turvastunud paepealsetes (Gh_1) muldades. Liigniiskus võib olla tingitud kõrgematelt aladelt sulglohkudesse pealevalguvast pinnaveest, kõrgest põhjaveeseisust või survelisest põhjaveest. Vastavalt veeoludele eristatakse paepealsete muldade hulgas aeromorfsed (põuakartlikud ja parasniisked) ning hüdromorfsed (niisked, märjad ja turvastunud) mullad. Turvastunud paepealsed mullad on valdaval osal vegetatsiooniperioodist küllastatud veega kuni maapinnani.

Profiilid. Mullaprofiili ülesehitus kajastab nii mulla mineraalses kui ka orgaanilises osas toimunud mullatekkeprotsesse ja on seega veeolude kõrval oluliseks teabeks mullaliigi määramisel. Paepealsete muldade väikesele tüsedusele vaatamata, võib nende hulgas olla vägagi erineva horisontide kombinatsiooniga mullaprofiile. Paasi kaetust õhukese moreenikihiga näitab huumus-(A-)horisondi all olev C- (lähtekivim) või AC-horisont. Rohkesti raudkivimaterjali sisaldava moreeni korral on A-horisont õhem ja selle all võib leida sisseuhte (B- või BC-horisondi) tunnuseid. Pinnalt tugevasti murenenud pae (R-horisont) korral saab eristada AR-horisondi (foto 1). Looduslikele paepealsetele muldadele on iseloomulikud metsa või rohumaade kõduga (O-horisont) algavad profiili valemid, millistes üleminekuhorisontidena võivad esineda vastavalt AB- ja AC-horisondid.

Foto 1. Paepealne muld pinnalt hästimurenenud pael (foto Illar Lemetti)
Photo 1. *Limestone rendzina on well disintegrated limestone (Photo by Illar Lemetti*)

Foto 2. Paepealne muld vähemurenenud pinnaga pael. Oidermaa (foto Endla Asi, BioSoil projekt)
Photo 2. *Limestone rendzina on non-weathered from the surface limestone (*Photo by Endla Asi, BioSoil project)

Valdavateks looduslike paepealsete muldade profiilideks (väljendatult profiili valemiga) on:

Kh' Kh"	O–A–R; O–A–BC–R; O–A–C–R
Kh'g Kh"g	O–A–R; O–A–BCg–R; O–A–Cg–R
Gh' Gh"	O(T)–AT–(CG)–R
Gh1	O–T3–(CG)–Rg

Paepealsete muldade profiili ülesehituses kajastuvad ka maakasutuse iseärasused. Harimise korral on pindmised orgaanilise aine rikkad (O, A või AT) horisondid harimise sügavuse ulatuses läbi segatud. Selle tagajärjel kaob looduslikele muldadele iseloomulik orgaanilise aine kihiline lasuvus. Lisaks sellele kantakse harimise käigus alumiste kihtide rähka haritavasse (Ak) horisonti.

Orgaanilise aine akumuleerumine mulda. Paepealsete muldade tuhaelementide ja lämmastiku poolest rikas varis soodustab orgaanilise aine laguproduktide küllastumist ja kiiret muundumist maapinnal. Bakteriaalne lagunemine toimub eriti intensiivselt niiskel ja soojal kevad- ja sügisperioodil, kuid võib peatuda kuival suvel. Mullaelustiku tegevuse tagajärjel seguneb taimne vare lubjarikka mullaga ja laguneb valdavas osas 1/2 või ühe suve jooksul. Tekkinud õhuke detriitne (purujas) metsakõdu (Od-horisont) on segunenud mineraalsete agregaatidega, kusjuures kohati metsa-(rohumaa-)kõdu kesksuvel praktiliselt puudub.

Looduslike paepealsete muldade rohurinde värske juurevarise pidev juurdetulek mulla pindmisse kihti soodustab kamardumist ehk huumus- (A) või toorhuumusliku (AT) –horisondi moodustumist. Kaltsiumirikkus, mullapõud ja taimejuurte suur hulk tagavad keemiliselt püsiva neutraalse huumuse tekkimise. Ajutine mullakuivus (ka niisketel muldadel) pärsib karbonaatses keskkonnas orgaanilise aine mineraliseerumist ja see akumuleerub pooleldi lagunenud kujul. Paepealsete muldade huumuse koosseisus on ülekaalus kaltsiumiga seotud huumushapped, samas on vabade fulvohapete osatähtsus tühine. Osa huumusest on mulla mineraalosaga hoopiski seostumata ehk inertne.

Paepealsete gleimuldade pikaajalisem liigniiskus ja valitsev anaeroobsus pidurdavad oksüdeerumis- ja humifikatsiooniprotsesse. Looduslike paepealsete gleimuldade õhukesele kihistumata metsa- või rohumaakõdule järgnev tüse vähehumifitseerunud ja tihkestumata huumusega kaltsiumirikas AT-horisont sisaldab rohkesti poollagunenud ja nõrgalt mulla mineraalsete osadega seotud orgaanilist ainet või on olemas isegi õhuke (<10 cm) turbakiht. Alalise liigniiskuse tõttu on bioloogiliselt tegus mullakiht õhuke, mistõttu puistute juurestik hõlmab vaid mulla pindmise osa ning paelõhedes olevad ressursid jäävad kasutamata.

Turvastunud paepealsete muldades varis enamasti ei mineraliseeru, vaid ladestub eutroofse hästilagunenud turbana mulla pinnale. Taoline turvas on valdavalt lämmastikurikas. Turvastunud paepealsed mullad saavad moodustuda vaid looduslikel aladel.

Huumusseisund ja huumuskatte tüüp. Mulla huumusseisundit ehk mulla orgaanilise aine majandust kajastab orgaanilist ainet sisaldavate horisontide (O, A, AT, T) morfoloogia (koosseisu ja tüseduste) kõrval ka nende huumuse- ja üldlämmastiku sisaldus ja varud (tabel 1). Huumusesisaldust väljendatakse kas orgaanilise süsiniku (Corg) või huumusesisalduse kaudu. Looduslike aeromorfsete paepealsete (Kh) muldade A-horisondi keskmised Corg ja huumuse kontsentratsioonid (137–151 g kg^{-1} ehk 13,7–15,1%) on oluliselt kõrgemad võrreldes haritavate muldade künni-(Ak-)horisondi (48–62 g kg^{-1}) omaga. Seoses liigniiskuse määra ja kestuse suurenemisega muutuvad paepealsed mullad järjest toorhuumuslikemaks ehk nendes suureneb pooleldi humifitseerunud orgaanilise aine osakaal. Olenevalt pae sügavusest, st mullakihi tüsedusest, varieeruvad paepealsete muldade Corg varud (70–200 Mg ha^{-1} ehk tonni hektari kohta) suurtes piirides.

Paepealsete muldade metsakõdu Corg varud on tavaliselt <10 (6,0–9,4) Mg ha^{-1}, kuna valdav osa orgaanilisest ainest (>90%) on akumuleerunud A- või AT-horisonti. Paepealsete muldade huumusvarule lisandub veel ka paelõhedes ja juurekäikudes olev huumus, milles on *ca* 6–12 tonni Corg hektari kohta. Paepealsed mullad on rikkad ka lämmastiku poolest, kusjuures C:N suhe on suurem metsamuldades, eriti selle turvastumisel.

Tabel 1. Eesti paepealsete muldade huumusseisundi näitajad
Table 1. *Humus status characteristics of Estonian limestone rendzina*

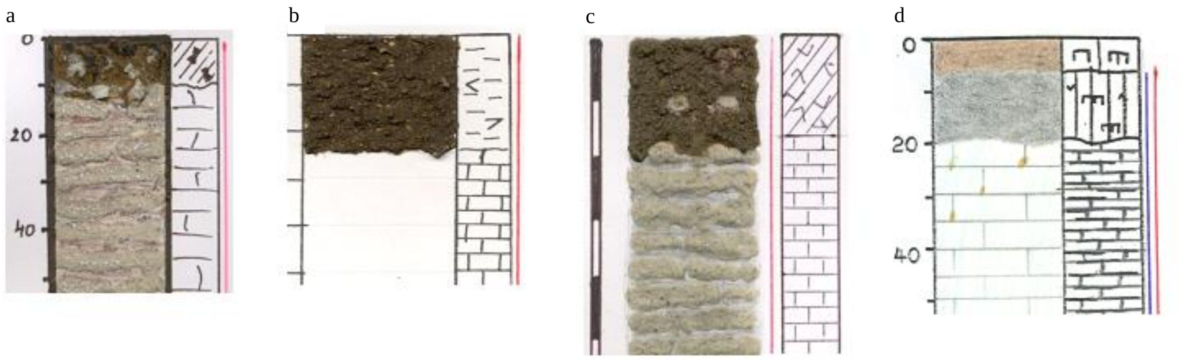
Muld *Soil*	Horisont *Horizon*	Olek[1)] *Status*	Sisaldus[2)]/*Content,* g kg^{-1}		Corg varu/*stock3)*, Mg ha^{-1}	Nüld/*Ntot* g kg^{-1}	Nüld/*Ntot,* Mg ha^{-1}	C:N
			Corg	Huumus/*Humus*				
Kh"	A	ld.	78−90	137−151	71−87	4,3−5,3	3,7−4,5	18−19
Kh"	Ak	hr.	26−38	48−62	70−80	2,6−3,4	6,0−7,2	10−12
Kh"g	A	ld.	81−93	143−157	74−85	4,4−5,4	3,8−4,4	19−20
Gh"	AT	ld.	84−96	148−162	80−85	4,5−5,3	4,1−4,5	18−20
Gh1	T	ld.	450−510	>900	140−200	20−24	8−10	18−22

1) Olek/*Status*: ld. – looduslik/natural, hr. – haritav/arable; [2)] Mullapeeneses /*In fine earth*: [3)] Mg – megagrammi ehk tonni hektari kohta / *in megagrams or tons per hectare*

Looduslike ja ülesharitud paepealsete muldade huumuskatte tüübid mullaliikide lõikes on järgmised (EMDK, 2008):

Kh' Kh" (ehk Kh)	Kuiv ja värske kaltsimull	Pehmehuumuslik rähkne (karbonaatne)
Kh'g Kh"g (ehk Khg)	Niiske kaltsimull	Pehmehuumuslik rähkne (karbonaatne)
Gh' Gh" (ehk Gh)	Märg kaltsimull	Toorhuumuslik eutroofne
Gh1	Turvastunud mull	Toorhuumuslik eutroofne

Nagu eeltoodust selgub on paepealsete muldade huumuskatted erinevad mulla loodusliku ja kultuuristatud oleku korral. Looduslike huumuskatete tüübi määramisel on olulisemad just veeolud, mitte aga niivõrd horisontide tüsedused. Valdavalt koosnevad paepealsete muldade huumuskatted õhukesest (1–2 cm) kõdu- ja maksimaalselt kuni 25–30 cm tüsedusest A- või AT-horisondist. Mull-tüüpi huumuskatetele on iseloomulik suur neutraalse (küllastunud) huumuse sisaldus, aktiivne mullaelustiku tegevus ja bakteriaalse lagunemise ülekaal seenelise lagunemise suhtes. Kaltsimull viitab huumuskatte lubjarikkusele, kuna huumuse koostises on ülekaalus kaltsiumiga seotud huumushapped. Huumuskatete veeolude reas kuivadest märgadeni suureneb mulla orgaanilise osa hulgas pooleldi lagunenud varise osakaal, kuid samas väheneb hästihumifitseerunud aine osakaal. Turvastunud mulli puhul on sisuliselt tegemist toitainete-rikka (eutroofse) hästilagunenud turbaga. Võib järeldada, et huumuskatte tüübid kajastavad hästi loopealsete maastike olemust nende lubjarikkuse, veeolude ja orgaanilise aine iseloomu poolest. Joonisel 2a ja 2d kujutatud huumuskatted pärinevad looduslikelt muldadelt, 2b ja 2c aga kultuuristatud muldadelt (joonis 2).



Joonis 2. Erineval moel dokumenteeritud paepealsete muldade huumuskatted (a – kuiv kaltsimull (r_3ls_2/p); b – pehmehuumuslik karbonaatne (rsl/p); c – pehmehuumuslik rähkne (r_2ls_2/p); d – märg kaltsimull ($t_{2\text{-}3}$/r_1ls_1/p))
Figure 2. *Humus covers of limestone rendzina documented by different way (a – dry calci-mull* (r_3ls_2/p)*; b – mild humous calcaric (rsl/p); c – mild humous skeletic (or ryhki)* (r_2ls_2/p)*; d – wet calci-mull* ($t_{2\text{-}3}$/r_1ls_1/p)*)*

Paepealsete muldade ülesharimisel orgaanilise aine mineraliseerumine tavaliselt kiireneb. Samas paranevad tingimused humifitseerunud orgaanilise aine küllastumiseks ja selle liitumiseks kattekihina mulla mineraalsetel osistele. Märgade paepealsete (Gh ja Gh1) muldade huumuskatte muundumist ülesharimisel tuleks võtta rohkem kui teoreetilist võimalust, sest need mullad on õigem jätta looduslikku seisu.

Lõimised ja erimid. Mullaliigid jaotatakse nende lõimise järgi mullaerimiteks. Mulla lõimise ehk granulomeetrilise koostise iseloomustamisel võetakse arvesse nii mulla kores (osakesed Ø üle 1 mm) kui ka mulla peenes (osakesed Ø alla 1 mm). Paepealsete muldade valdavad (umbes 88%) lõimised on liivsavid (ls) ehk täpsemini kerge (ls_1) ja keskmine liivsavi (ls_2). Ülejäänud paepealsete muldade valdav lõimis on saviliiv (sl), sest raske lõimisega muldi (ls_3 ja s) on paepealsete muldade hulgas alla ühe protsendi.

Paepealsete muldade koresesisaldus sõltub paasi katva moreeni rähksusest, pae murenemisastmest ja maakasutusest. Looduslike paepealsete muldade huumushorisondis ei leidu rähka (r) üldse või leidub väga vähe. Haritavatel paepealsetel muldadel on rähk põllutööde käigus sattunud ka mulla haritavasse kihti. Nende muldade valdavaks erimiks on keskmiselt rähkne (r_2) liivsavi (ls), millele järgneb tugevasti kuni väga tugevasti rähkne liivsavi ($r_{3\text{-}4}$ls), mis lasub pael (p) ehk selle erimi valemiks on – $r_2$ls/$r_{3\text{-}4}$ls/p. Rohkesti on ka haritavaid muldi, milledes nõrgalt rähkne (r_1) liivsavi lasub vahetult pael ($r_1$ls/p). Looduslike mineraalsete paepealsete (Kh, Khg ja Gh) muldade pealmine lõimis on enamasti rähavaba liivsavi (ls), millele järgnevad keskmiselt kuni tugevasti rähksed liivsavid ($r_{2\text{-}3}$ls), lausaldane rähk (r) ja paas (p) ehk lõimisevalem on – ls/$r_{2\text{-}3}$ls/r/p. Samas on looduslikel aladel ka palju paepealseid muldasid, mille pealmiseks lõimiseks on nõrgalt kuni keskmiselt rähkne liivsavi ning vahetult pael asuvad kihid on tugevasti kuni väga tugevasti rähksed ($rls_{1\text{-}2}$/$r_{4\text{-}5}$ls/p).

Üksnes paekivimi murendist koosnevaid raskema lõimisega paepealseid muldasid esineb piiratult. Põhiosas on paepealsetel aladel tegemist rähksest liivsavimoreenist moodustunud mullaerimitega. Selle tunnuseks on tard- ja moondekivimilise kruusa, veerise ja kivide esinemine. Turvastunud paepealsete mullaerimite (Gh1) pindmiseks kihiks on hästilagunenud turvas (t_3) ning erim valemiteks vastavalt t_3/p või t_3/r/p.

Füüsikalised, keemilised ja veeomadused. Paepealsete muldade lasuvustihedus on väike (tabel 2), sest nad sisaldavad palju huumust ja on hästi struktuursed. Vastupidav teralis-tompjas struktuur on eriti hästi välja kujunenud liivsavi lõimise korral. Aeromorfsed paepealsed mullad on seega poorsed, hästi õhustatud ja hea loodusliku drenaažiga, mille tõttu sademete ja lumesulamise vesi pääseb hästi ära voolama ja mullas on valdavalt head tingimused oksüdatsiooniprotsessideks.

Tabel 2. Paepealsete muldade O-, A-, AT- ja T-horisondi füüsikalised omadused
Table 2. *Physical properties of O-, A-, AT- and T-horizons of limestone rendzina*

Muld[1)] *Soil*	Horisont *Horizon*	Lasuvus-tihedus *Bulk density* g cm^{-3}	Üldine poorsus *Total porosity* %	Eripind *Specific surface area* m^2 g^{-1}
Kh" mts	O	0,09−0,11	90−94	300−350
Kh" mts	A	0,9−1,2	48−52	100−150
Kh" pld	Ak	1,2−1,4	44−48	80−100
Kh"g mts	A	0,8−1,1	50−60	90−150
Gh" mts	AT	0,5−1,0	60−80	100−200
Gh1 mts	T	0,15−0,21	80−90	300−400

[1)] mts – metsamuld / *forest soil*, pld – põllumuld / *arable soil*

Kh muldade huumushorisondi keskmised pH_{KCl} on looduslikes ja haritavates muldades vastavalt piirides 5,4–6,3 ja 6,6–7,3 (tabel 3). Looduslike paepealsete muldade huumushorisondi reaktsioon on ülemises 10 cm mullakihis natuke happelisem ja vertikaalselt diferentseerunud võrreldes haritavate muldadega. Hüdrolüütiline happesus on paepealsetes muldades väga väike või praktiliselt puudub. Nendel muldadel puudub asendushappesus ning ei esine taimedele toksilist liikuvat alumiiniumi. Küllastusaste on kõrgem haritavatel paepealsetel muldadel (vastavalt 90–95% ja 94–98%). Erandjuhtudel, kui mullapind on õhukeselt kaetud karbonaadivaese materjaliga (liiv), võib küllastusaste langeda ka alla 80%. Valdava osa kogu neelamismahutavusest moodustavad neeldunud alused, samas on mulla neelamismahutavused enam-vähem võrdsed (27–33 cmol kg^{-1}) looduslikes ja kultuuristatud muldades. Kui küllastusaste suureneb sügavuse suunas, siis neelamismahutavus vastupidiselt sellele väheneb.

Tabel 3. Paepealsete muldade O-, A- ja AT-horisondi agrokeemilised[1)] omadused
Table 3. *Agrochemical properties[1)] of O-, A- and AT-horizons of limestone rendzina*

Muld *Soil*	Horisont *Horizon*	pH_{KCl}	$H_{5,6}$, cmol kg^{-1}	Al mg kg^{-1}	$H_{8,2}$ (cmol kg^{-1})	S (cmol kg^{-1})	T (cmol kg^{-1})	V, %
Kh" mts	O	4,8−5,1	1,0−1,2	6,4−6,8	35−43	36−44	70−90	45−55
Kh" mts	A	5,4−6,3	0,0	0,5−1,5	2,5−3,5	26−34	29−34	90−95
Kh" pld	Ak	6,3−7,3	<0,1	<0,2	0,6−1,6	24−32	26−32	94−98
Kh"g mts	A	5,2−6,2	0,0−0,3	1,5−2,5	2,6−3,6	25−33	28−34	87−93
Gh" mts	AT	5,1−6,0	<0,5	1,8−2,8	6,0−6,8	25−34	31−39	80−90

[1)] Agrokeemilised omadused / *Agrochemical properties*: $H_{5,6}$ – asendushappesus / *exchangeable acidity*, Al – liikuv alumiinium / *mobile aluminium*, $H_{8,2}$ – hüdrolüütiline happesus / *hydrolytical acidity*, S – neeldunud alused / *basic cations*, T – neelamismahutavus / *cation exchange capacity*, V – küllastusaste / *stage of base saturation*

Piki klindi piirkonda Narva-Jõesuust kuni Keilani kulgeva fosforirikka vööndi (laius 5–15 km) alas ulatub üldfosfori sisaldus sageli üle 15 g kg^{-1}, mis on tingitud seal avanevatest oobolusliivakivi lademetest. Ka mulla huumushorisondi liikuva fosfori sisaldus on selles vööndis enamasti väga suur (>175 mg kg^{-1}). Väiksem on fosforisisaldus sisemaa poole jäävates muldades, ulatudes harva üle keskmise (35–60 mg kg^{-1}). Paepealsed mullad on rikkad mikroelementide (vask, koobalt, boor, mangaan) poolest.

Enamik paepealsetest muldadest on suure väliveemahutavusega (kuni 60% maksimaalsest veemahutavusest). Sõltuvalt huumusesisaldusest ja lõimisest on nende huumushorisondi maksimaalne hügroskoopsus suure varieeruvusega (>20%). Et aga mullakiht on õhuke, on taimedele kättesaadav veevaru väga väike, alla 50 mm. Suurele eripinnale vaatamata on nad siiski (sõltuvalt väikesest tüsedusest) põuakartlikud. Mida rohkem sisaldab huumushorisont korest, seda väiksem on tema vett hoidva mullapeenese osa. Rohkete lõhedega ja pealmises osas murenenud paas soodustab sademevee kiiret äravalgumist.

Taimkatte põuakahjustusi esineb enamikul aastatel kõigil aeromorfsetel paepealsetel (Kh) muldadel, vähem aga gleistunud paepealsetel (Khg) muldadel. Gleistunud paepealsete muldade produktiivsust limiteeriv tegur on ajutise liigniiskuse kõrval ka nende väike mullaprofiili aktiivveemahutavus (koreserikastes muldades <100 mm).

Talitluslikud iseärasused. Aeromorfsed hea loodusliku drenaaži ja struktuuriga paepealsed mullad soojenevad kevadel kiiresti. Suvel kuivab muld läbi, mille tõttu pidurdub orgaanilise aine mineralisatsioon. Talvel langeb mulla temperatuur aga pae läheduse tõttu madalamale võrreldes sügavamate muldadega.

Paepealsete gleimuldade (Gh, Gh1) veega küllastatus muudab nad külmaks ja aeglaselt soojenevaks, mistõttu kevadine vegetatsioon algab neil ligemale kaks nädalat hiljem võrreldes parasniiskete Kh muldadega. Kevade ja sügisene veega küllastatus põhjustab taandusprotsesside ülekaalu mullas, mis loob neis soodsad tingimused toorhuumuse tekkeks ja turvastumiseks. Suvel, mulla veevarude vähenedes, tuleb mulda rohkem nii atmosfääriõhku kui ka juurte hingamisel vabanenud süsihappegaasi ning intensiivistub orgaanilise aine lagunemine ja humifitseerumine. Tunduvalt aeglasemalt toimub see muidugi turvastunud muldades. Liikuva või kiiresti vahelduva kaltsiumirikka mullavee tõttu kujuneb paepealsetes gleimuldades siiski suhteliselt hea keskkond nii juurte arenguks kui ka mullaelustiku tegevuseks, sest liikuv mullavesi sisaldab seisvast veest rohkem hapnikku.

Paepealsete muldade taimkate, produktiivsus, kasutamine ja kaitse. Looduslikel paepealsetel metsa- ja rohumaamuldadel kasvab lubjalembene taimestik. Väga õhukestel paepealsetel muldadel (Kh', Kh'g, Gh') domineerivad madalaboniteedilised (V–Va) leesikaloo männikud, vähem esineb kuusikuid ja kaasikuid. Viljakamatel paepealsetel muldadel kasvavate kastikuloo kuuse-männi segapuistute boniteet on kõrgem (valdavalt IV). Raskesti metsastuvate paepealsete glei- ja turvastunud (Gh, Gh1) muldade boniteet on madal

(IV–Va) ebastabiilse niiskusrežiimi tõttu. Niisketele (Khg) ja märgadele (Gh) paepealsetele muldadele on omased lubikaloo leht- ja okaspuu segametsad.

Loometsade puistud on üldiselt hõredad, kuid alusmets on liigirikas (sarapuu, magesõstar, kuslapuu, kadakas, lodjapuu, kibuvits jt). Aeromorfsete paepealsete muldade lubja- ja kuivuselembene alustaimestik koosneb kuivadele ja parasniisketele oludele sobivatest liikidest, sisaldades rohkesti ka liblikõielisi. Taimkattele on iseloomulik tugevasti arenenud juurestik, kuid kääbustunud maapealne osa. Kuivadel aegadel jäävad läbikuivanud mullale kasvama vaid vastupidavad taimeliigid (harilik keelikurohi, varretu ohakas jt). Niisketele ja märgadele paepealsetele muldadele on iseloomulikud lubikas, vesihaljas tarn, hirsstarn, angerpist, tedremaran jt. Kuid samblaid (metsakäharik, niiduehmik, roossammal, tähtsammal) esineb vähesel arvul vaid mätastel.

Aladel, kus mets pole suuteline arenema, levivad liigirikka rohurindega kadaka-karjamaad. Gh muldadele kujunevad niitmise mõjul lubika poolest rikkad kooslused vesihalja tarna, ääristarna, hirsstarna, põõsasmarana, pääsusilma ja teiste liikidega. Gh1 muldadel lisanduvad neile pruuni sepsika kooslused.

Paepealsete põllumuldade osatähtsus teiste hulgas on väike (alla 1%). Paepealsete haritavate maade (tavaliselt Kh'' ls/p) boniteet on 25–33 hindepunkti piires ehk tegemist on alla keskmise viljakusega mullaga. Saagikust limiteerib väike aktiivvee mahutavus. Põlluna kasutamiseks peaks paepealse mulla huumushorisondi tüsedus olema üle 20 cm. Suhteliselt paremini suudavad paepealsed mullad rahuldada põuakindlate, vett ökonoomselt kasutavate ja lubjalembeste kultuuride vajadusi. Teraviljadest on selline oder, heintaimedest lutsern.

Paepealsed mullad on oma põuakartlikkuse tõttu madala efektiivse, kuid kõrge potentsiaalse mullaviljakusega. Väga õhukesed paepealsed mullad jäetakse looduslikku seisu või kasutatakse looduslike karjamaadena. Looduslike rohumaade saagikus neil muldadel jääb tavaliselt piiridesse 0,4–0,5 tonni kuiva heina hektari kohta. Nendel kasvavaid metsi tuleb hoolega säilitada, sest mets ei ole väga õhukestel looaladel praktiliselt võimeline looduslikult taastuma (Reintam, Rooma, 2001).

Vastupidava mullastruktuuri tõttu on paepealsed mullad harimiskindlad. Mulla tehnoloogilistest omadustest on paepealsete muldade puuduseks pae lähedus ja räha või paeplaatide esinemine haritavas mullakihis. Koreserikkad paepealsed mullad on raskelt haritavad, mille tõttu on nad põllumajanduse seisukohalt piiratud kasutussobivusega. Rühvelkultuuride vaheltharimisel tekib taimedel olulisi kahjustusi ja kartuli mehhaniseeritud koristamine pole võimalik. Haritavate maadena tulevad nad kõne alla Loode- ja Lääne-Eestis, kus nad moodustavad suuremaid ühtlase mullastikuga põllumassiive.

Gleistunud paepealsed ja paepealsed gleimullad on kasutusel looduslike rohumaade ja metsamaadena oma piiratud kasutussobivuse või põllumajanduslikuks kasutamiseks mittesobivuse tõttu. Paepealsete gleistunud ja gleimuldade (sh turvastunud) ülesharimisest tuleks hoiduda, sest siis nende suhteliselt suured orgaanilise aine varud mineraliseeruvad kiiresti. Eelistatult parimaks märgade paepealsete muldade kasutusviisiks tuleks pidada looduslikke rohumaid, sest paljude metsapuuliikide kasvuks ei ole need mullad sobivad (Foto 3).

Foto 3. Tuuleheide paepealsel gleimullal. Mõõduks on kahemeetrine mõõtelatt 1 dm jaotistega (foto: Illar Lemetti)
Photo 3. *Windfall on limestone gley-rendzina. For measure the two metre rod with 1 dm divisions is used (Photo by* Illar Lemetti)

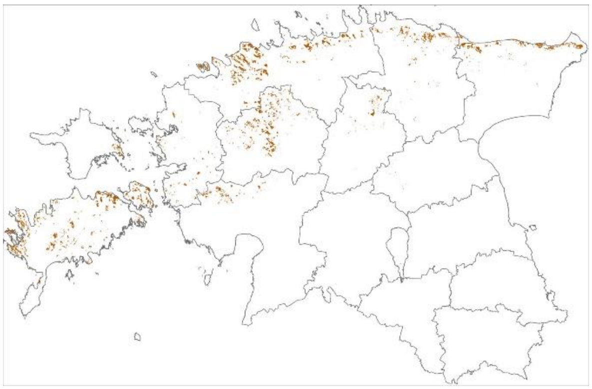
Levik ja seotus teiste muldadega. Paepealsed mullad (kuivadest kuni märgadeni) levivad loopealsetel, s.o kitsa ribana Põhja-Eesti paekalda sisemaapoolsel küljel (Foto 4).

Foto 4. Klindiala paetasandikel on levinud paepealsed mullad, klindi jalamil aga rusukalde mullad. Päite pank (foto: Indrek Tamm
Photo 4. *On the plains of limestone glint (steep bank) the limestone rendzina, but on the foot of the glint the scree debris soils are distributed (Photo by:* Indrek Tamm)

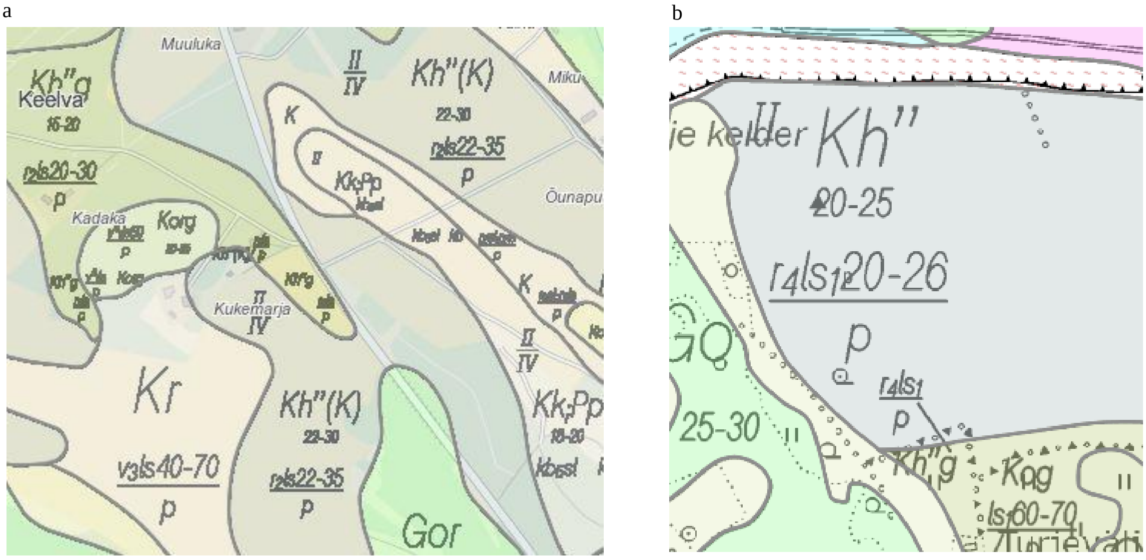
Kõige rohkem on neid Ida-Virumaal, Harjumaal ja Lääne-Virumaal. Suuremad paepealsete muldade massiivid asuvad veel ka Saaremaal, Hiiumaal ja Läänemaal (joonis 3).

Agromullastikulistest mikrorajoonidest on paepealseid muldi enam Maardus, Keilas ja Heltermaal (Kokk, Rooma, 1974). Suurima osa põllumaast (12–30%) moodustavad paepealsed mullad Maardus, Aseris, Ilumäel ja Keilas. Niiskeid ja märgi paepealseid muldi põllumaadena praktiliselt ei kasutata.

Paepealsete muldadega kaasnevad mullaliigid reljeefi kõrgematel osadel on erineva sügavusega rähkmullad, madalamatel niiskematel osadel aga gleistunud rähksed ja leostunud mullad (joonised 1b, 4a, 4b). Veelgi madalamatel maastikuosadel esinevad kas rähksed, leostunud ja küllastunud gleimullad või küllastunud turvastunud ja madalsoo-mullad.



Joonis 3. Paepealsete muldade levik Eesti maakondades (koostanud: Priit Penu, Tambet Kikas)
Figure 3. *Distribution of limestone rendzina in Estonian counties (Compiled by* Priit Penu, Tambet Kikas)



Joonis 4. Väljavõtted paepealsete muldadega suuremõõtkavalisest (1:10 000) mullastiku kaardist (a – Keelva; b – Uuri) (Allikas: Eesti mullastiku kaart Maa-ameti geoportaalis)
Figure 4. *Excerpts with limestone rendzina from the large scale (1:10,000) soil map (a – Keelva; b – Uuri) (Source: Estonian Soil Map at Estonian Land Board Geoportal)*

Mulla nimetus *World Reference Base for Soil Resources* järgi. Ülemaailmse mullaressursside määratlemise või viite baasi *(World Reference Base for Soil Resources,* WRB) järgi kuuluvad paepealsed mullad *Leptosol*'ide hulka, mis on üks WRB referentsmuld kolmekümne kahest (Kõlli, 2000; IUSS, 2014). Kuulumist sellesse referentsmuldade rühma näitab õhuke (*leptic*) peeneselise mulla kiht, mille tüsedust limiteerib kivistunud (*lithic*) lubipaas. Oluline tunnus on karbonaatide poolest rikka pehmehuumusliku *(rendzic)* huumuskatte olemasolu. Tunnussõna (kvalifikaator) *rendzic* kätkeb endas ühtaegu nii pehmehuumuslikkust (*mollic*) kui ka karbonaatsust (*calcaric*) ja toiteelementide rikkust (*eutric*). WRB sisaldab üldiselt piisavalt sobivaid tunnussõnu paepealsete mullaliikide üksteisest eristamiseks. Gh1 on näiteks *Saprihistic Calcaric Lithic Leptosol*, kus *saprihistic* tähendab hästilagunenud turvast. Põhinimetuse järgsetes sulgudes saab ära näidata gleistumise (*gleyic*), huumuserikkuse (*hyperhumic*), kasutamise haritava maana (*aric*) ja kuivendussüsteemide olemasolu (*drainic*). Mulda saab WRB-s näidata ka erimi tasemel, sealjuures liivakas, savikas, liivsavikas ja tolmjas väljendatakse vastavalt täienditega *arenic/ clayic/loamic/siltic*. Näiteks, kui on tegemist gleistunud haritava mullaga, siis tuleks sulgudes lisada teiste vajalike tunnuste kõrval ka *aric* ja *gleyic*. Eestis valdava paepealse mullaerimi – õhukese paepealse liivsavi (Kh'' ls/p) – nimetus WRB järgi on seega '*Rendzic Lithic Leptosol (Loamic, Hyperhumic)*', mille kood on: LP-li.rz-lo.jh.

Leptosolide kui WRB referentsmuldade hulka kuuluvad ka õhukesed koreserikkad rähkmullad *(Skeletic Leptosols)*, millistel on õhukese huumuskatte all massiivse pae asemel rähk, klibu, veeris või muu karbonaatne kores.

Arutelu ja järeldused

Eesti paepealsete muldade uurimine ja seisund

Eesti muldkattes on paepealseid muldi veidi alla 50 000 hektari. Suurema osa nendest muldadest moodustavad parasniisked ja/või põuakartlikud liigid (*ca* 42%). Niiskete, märgade ja turvastunud paepealsete muldade osakaal on aga väiksem (vastavalt 28%, 20% ja 10%). Muldade tüseduse järgi võttes ületab õhukeste paepealsete muldade pindala (81%) väga õhukeste (19%) pindala (Rooma, 1976). Kõlvikutest moodustavad nad suurema osa looduslikel rohumaadel *ca* 7%, kuid metsa- ja haritavate muldade hulgas on neid muldi alla 1%. Haritava maana on paepealsetest muldadest kasutusel *ca* 19%. Kõigi kõlvikute valdavateks erimiteks on aga liivsavid (Kokk, Rooma, 1974).

Eesti mullastiku detailset analüüsi on otstarbekas teha Eesti muldade klassifikatsiooni liigi ja/või erimi tasemel. See kehtib nii suuremõõtkavaliste (1:10 000) mullastikukaartide tegemisel ja kasutamisel, kui ka kohtpaiksusel põhineva täppismaaviljeluse puhul. Muldkatte käsitlemist mullaliigi ja/või mullaerimi tasemel võimaldab vastavate muldade või nende domineerivate variantide keskmiste mudelite olemasolu (Kokk, Rooma, 1978; Kokk, 1983; EMDK, 2008).

Teatavasti seisneb EPP MUO poolt juurutatud ja ka mullateaduse alases õppetöös kasutatav printsiip selles, et mistahes konkreetsele mullaerimile hinnangu andmiseks võrreldakse selle olemasolevaid karakteristikuid mudelmulla karakteristikutega. Mudelmulla erimi keskmised näitajad ja selle kõikumise piirid on saadud mitmekümne kuni mitmesaja üksikprofiili näitajate alusel. Kasutades lisaks teadmisi näitajate seaduspärastest muutumistest seoses veeolude ja lõimisega muutustega on võimalik anda hinnanguid ka vähemlevinud erimite kohta, mille kohta keskmisi näitajaid (mudeleid) pole seni veel tehtud.

Paepealsete muldade osas on mudel olemas haritava maa õhukese paepealse liivsavimulla (ls_1) ja metsamaa õhukese paepealse savimulla (ls_3) kohta (EMDK, 2008). Graafiliste mudelite algallikaks on olnud seeriaväljaande *Eesti NSV mullastik arvudes* publitseeritud andmed, kus peale mullaerimit iseloomustavate karakteristikute statistika on antud ka ühe või teise keskmise näitaja aluseks olnud mullaprofiilide (kaevete) arv. Nii on põllumullaerimi Kh'' ls/p mudeli aluseks olnud 110 kaevet, ning metsamullaerimi Kh'' s/p aluseks olnud 29 kaevet (Kokk, Rooma, 1978; Kokk, 1983).

EPP MUO poolt on paepealseid muldi uuritud ka vaatlusaladel (Muuksi, Rapla), mille alusel on selgitatud nende iseärasusi maakasutuse (looduslik rohumaa, mets, põld) ja erimite (saviliiv, liivsavi (ls_1 ja ls_2), savi (ls_3)) alusel (Kokk, 1987). Artikli autori poolt formeeritud ökosüsteemi tasemel uuritud andmebaasis *Pedon* on paepealse mullaga ökosüsteeme kokku 18 (metsamuldadel 6, põllumuldadel 8 ja rohumaamuldadel 4) ning andmebaasis *Epipedon* kokku 5 looduslike paepealsete muldadega uurimisala (Kõlli, 1988).

Loodetavasti saavad EPP MUO poolt kogutud ja süstematiseeritud ning seeria "Eesti NSV mullastik arvudes" I–VIII köites publitseeritud andmed lähemal ajal digitaalsel kujul sisestatud Eesti looduslike varude andmebaasidesse, mis tagab nende parema kättesaadavuse säästva ja kestliku maakasutuse huvides. Jälgides asjade käiku riigi reformide tuultes ei jää märkamatuks kahju, mille on saanud Eesti mullastiku uurimine. Nii näiteks selgus EPP MUO mullauurija Rein Lehtveere ütlustest, et teadmata kadunuks on jäänud trükivalmis *Eesti NSV mullastik arvudes* IX ja X köite käsikirjad ning ka alustatud XI köite materjalid.

Eesti loodusteaduslike arhiivide (digiandmebaaside) NATARC või Eesti riigi Keskkonnaregistri loomisel on kavandatud oluline osa ka Eesti mullastiku andmetele. Kahjuks näitab seni tehtu ja avaldatu, et Eestile suunatud praktilised arendused on jäänud liialt tagasihoidlikeks ja ebapiisavateks võrreldes teiste aladega. Ilmselt ei ole asjaosalistel olnud piisavalt materiaalseid võimalusi või kompetentsust mullastiku rolli integreerimisel Eesti looduse kui terviku andmebaasi. On ju üldtuntud tõde see, et muldkate determineerib suurel ja tuntaval moel looduslike ökosüsteemide elurikkuse ja talitlemise iseärasused ning taimkatte ja kogu ökosüsteemi kohta kogutud andmestik jääb mulda kõrvale jättes piltlikult öeldes justkui "õhku rippuma".

Käesolev uuring tõestab veel kord, et pikka aega kasutusel olev Eesti muldade klassifikatsioon töötab hästi ning väärib seega rohket respekti. Eesti muldade klassifikatsiooni mullaliigi taseme taksonid on adekvaatselt konverteeritavad WRB süsteemi, mis loob aluse andmete korrelatsiooniks rahvusvahelisel tasemel. Küll aga tekib probleeme mullaerimite tasemel konverteerimisel, sest sootuks erinevad on olnud nii mullakorese kui ka mullapeenese klassifikatsioonid. Samas ei vajata praktiliste küsimuste lahendamiseks uusi analüüse, sest asja saab lahendada nii lõimiste paralleelsete nimetuste kasutamisega, kui ka lõimise analüüsi algandmete järgi uue nimetuse andmisega.

Tähtis on säilitada mistahes mullastikku puutuvate andmete puhul otsene side algmäärangutega st Eesti mullastiku klassifikatsiooniühikutega. Silmas tuleb pidada siinjuures asjaolu, et WRB kiire areng (suured muutused lühikese aja jooksul) võib kaotada ühenduse algmäärangutega ning seotus Eesti muldade klassifikatsiooni taksonitega muutub järjest kaudsemaks ja määramatumaks. Samas tuleks aga süsteemikindlalt muuta Eesti muldade klassifikatsiooni (sh paepealsete muldade osas) järjest paremini kokkulangevaks rahvusvaheliselt unifitseeritud süsteemidega.

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Soil on limestone – Year 2015 soil of Estonia

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Summary

By Estonian Soil Sciences Society for the year 2015 soil of Estonia the limestone rendzina was elected. After WRB these soils embrace different kind of Rendzic Lithic Leptosols. The area of limestone rendzinas forms 1.2% from the whole Estonian soil cover. In the overview on Estonian year 2015 soil the classification, morphology, genesis, humus status and different properties (chemical, physical, hydrophysical) are treated. The functioning and properties of limestone rendzinas are treated on soil species (identified by soil genesis) and soil varieties (divided on the basis of soil texture) levels. Besides abovementioned characteristics the limestone rendzinas' productivity, environment protection ability in dependence upon soil functioning and properties, and usage in agriculture and forestry are analysed. The distribution of limestone rendzinas is analysed in relation of whole Estonia, its Counties and agro-districts. In discussion the quality of legal data bases and actual state of Estonian limestone rendzinas are evaluated.

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TALIRUKKI 'VAMBO' SAAGIKUSEST JA SAAGISTABIILSUSEST PIKAAJALISES NPK VÄETUSKATSES RÄHKMULLAL

THE PRODUCTIVITY AND YIELD STABILITY OF WINTER RYE VARIETY 'VAMBO' IN LONG TERM NPK FERTILIZATION TRIAL ON CALCARIC CAMBISOL

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Link: http://agrt.emu.ee/pdf/2015_2_loide.pdf

ABSTRACT. The productivity and yield stability of winter rye has been investigated in long term fertilization trial on Calcaric Cambisol. The diploid rye variety 'Vambo' was one of the cultures used in the trial in years 1975 till 2014. The trial was established as six-year crop rotation (potato-late maturing spring barley-undersown early maturing spring barley-first year grass clover mixture-second year grass clover mixture-rye). In the trial the traditional agrotechnical measures were applied: ploughing, using of herbicides and plant protection measures. The trial consisted of 21 combined variants of NPK mineral fertilisers and farmyard manure variants of 30 and 60 t ha^{-1}. NPK-fertilizers (kg ha^{-1} as element) levels are as follow: 000 = $N_0P_0K_0$; 111 = $N_{45}P_{13}K_{30}$; 222 = $N_{90}P_{26}K_{60}$; 333 = $N_{135}P_{39}K_{90}$; 433 = $N_{180}P_{39}K_{90}$. Weather conditions of trial are given in figures 1–2.

Averagely of 19 years the rye yield from unfertilized plot (Figure 3) was 1.9 t ha^{-1}, by using of mineral fertilizers in level 3 ($N_{135}P_{39}K_{90}$) the yield was 4.1 t ha^{-1}. The effect of farmyard manure combined with mineral fertilizers was modest (Table 1) because the organic fertilizer was applied to the first culture in crop rotation (potato) and the last culture rye didn't get any benefit from that.

The weather conditions had bigger impact on yield than fertilization. Different fertilizing levels (Figure 4) have had positive effect on rye productivity, but the variability was remarkable. The increasing of productivity is most probably connected to the good weather conditions in September. But in the same time the variability in productivity was increased due to unfavourable conditions in September like the increasing of temperatures and decreasing of precipitation (dry periods in the beginning of rye growth). The best stability of yields was recorded in fertilization level 333 ($N_{135}P_{39}K_{90}$) where the average yield levels of 3–5 t ha^{-1} was 84%. In the same time the fertilization levels 222 and 221 gave the same productivity 74 and 53% accordingly. Compared to the smaller rates of fertilization the plots with higher fertilization rates (NPK 222 and higher) resulted in smaller variability in yields (Figure 6).

Sissejuhatus

Rukis *(Secale sereale* L.) on toiduviljana levinud Põhja- ja Ida-Euroopas ja Skandinaavias. Rukis kui Eesti rahva peamine leivavili on vähenõudlik kultuur ja kasvab hästi jahedamas kliimas. Talirukki juured on tugevama toitainete omastamise võimega ja kasutavad paremini raskesti kättesaadavaid toitaineid (Reeman, Tuppits, 1978). Rukis on olnud Eestis läbi aegade kõige stabiilsemaks ja ilmastiku suhtes kõige vastupidavamaks viljakultuuriks (Sirendi, 2014). Sordiaretustöö tulemusena aretati sort 'Vambo'. 'Vambo' on diploidne talirukis, mis erineb tunduvalt 'Sangaste'-

tüüpi sortidest kõrre ja pea pikkuse ning produktiivsuse poolest. Sordiõigused omistati talirukkile 'Vambo' 1973. aastal (Tupits jt, 1999). Vahetult uue ja kõrge saagipotentsiaaliga, 5500–6000 kg ha^{-1}, (Tupits jt, 1999) sordina võeti rukis 'Vambo' A. Piho poolt rajatud pikaajalise külvikorra NPK väetuskatse kultuuriks, mille kestus katses kujunes seni ilmselt üheks pikimaks (40 aastat). Mullastiku suhtes on rukis suhteliselt leplik, rahuldavat saaki annab ka väheviljakatel, põuakartlikel ja happelistel muldadel (Tupits, 2007). Ka liivsavi lõimisega rähkmuld on rukki kasvatamiseks hea sobivusega muld (Kõlli, 1994).

Rukis sisaldab palju toitaineid, mida muudes toiduainetes pahatihti napib, sealhulgas väärtuslikke kiudaineid, mineraalaineid, süsivesikuid, vitamiine jt, (Hansen jt, 2004; Kann, 2002; Mykkänen, 1995). Seetõttu, silmas pidades rukki tähtsust tervist edendava toiduviljana, tutvustatakse Eesti Rukkiaasta missiooni valguses alljärgnevalt ka pikaajalise NPK-väetuskatse tulemusi (aastaist 1975.–2012*)* talirukkiga 'Vambo' rähkmullal.

Materjal ja metoodika

Uurimistöö koostati pikaajalise külvikorra NPK-väetuskatse 1975–2012. aasta katseandmete baasil, mis rajati A. Piho (1973) poolt 1965.–1966. a Kuusikul Põhja-Eestis kergele liivsavisele rähkmullale (*Calcaric Cambisol*). Katsemulla agrokeemilised näitajad katse algul: pH_{KCl} 6,5–6,6; algmulla huumusesisaldus (Tjurin) 2,6%; liikuvate toiteelementide sisaldus Egner-Riehmi topeltlaktaat-väljatõmbes (DL) P – 14 mg kg^{-1} (madal); K – 96 mg kg^{-1} (keskmine). Katse oli neljas korduses kuni 1993. a, hiljem kahes korduses; katselapi mõõtmed 7,5 × 7,5 m. Rukis (*Secale cereale* L.) oli katses 6-väljalises külvikorras (kartul-hiline oder-varane oder allakülviga-1. a põldhein-2.a põldhein-rukis) 84 katselappi. Katses rakendati traditsioonilist agrotehnikat: künnipõhist, 0,22 m sügavuselt mullaharimist, puhitud seeme – külvinorm 500 id. tera m^{-2}, kõrrekoorimine, keemilist umbrohutõrjet ja taimekaitset. Katses on 21 NPK-väetistega ja tahke veise sõnnikuga kombineeritud väetusvarianti.

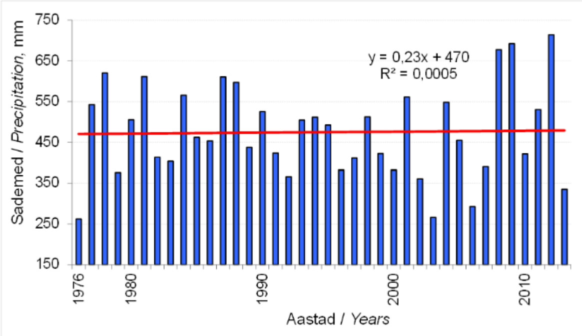
Väetusvariandid:
NPK, kg ha^{-1} ja sõnnik t ha^{-1}; variandi lühend

1	$N_0P_0K_0$	000	12	$N_{135}P_{26}K_{90}$	323
2	$N_{45}P_0K_0$	100	13	$N_{135}P_{39}K_{60}$	332
3	$N_{45}P_{13}K_0$	110	14	$N_{135}P_{39}K_{90}$	333
4	$N_{45}P_0K_{30}$	101	15	$N_{180}P_{39}K_{90}$	433
5	$N_{45}P_{13}K_{30}$	111	16	$N_{90}P_{26}K_{60+30*}$	222+30
6	$N_{90}P_{13}K_{30}$	211	17	$N_{135}P_{26}K_{60+30}$	322+30
7	$N_{90}P_{13}K_{60}$	212	18	$N_{180}P_{39}K_{90+30}$	433+30
8	$N_{90}P_{26}K_{30}$	221	19	$N_{90}P_{26}K_{60+60}$	222+60
9	$N_{90}P_{26}K_{60}$	222	20	$N_{135}P_{26}K_{60+60}$	322+60
10	$N_{90}P_{39}K_{60}$	232	21	$N_{180}P_{39}K_{90+60}$	433+60
11	$N_{135}P_{26}K_{60}$	322			

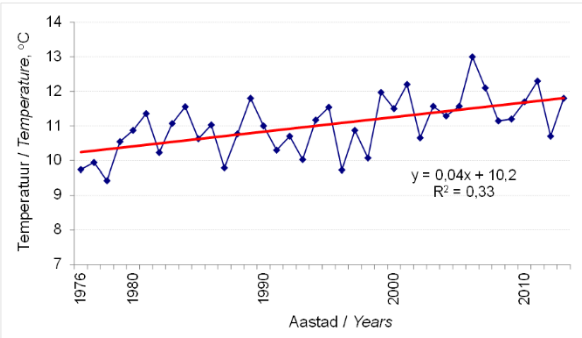
* külvikorras kasutatud sõnnik anti sügisel künni alla järgnevale, külvikorra esimesele kultuurile kartulile

Kasutatud väetised kogu katseperioodil: ammooniumsalpeeter, lihtsuperfosfaat, kaaliumkloriid. PK-väetis viidi mulda teise kultiveerimisega, lämmastik anti pealtväetisena aprillikuus, sh ka N_{180} (vastavalt metoodikale). Peenestatud teraviljapõhk segati koristuse järgselt kõrrekoorimisega mullaga ja viidi künniga mulda. Saak koristati optimaalsel ajal, määrati saak ja selle kuivaine. Tera- ja põhusaagi keemiline koostis (N, P, K) määrati kuivtuhastusmeetodil 1981–1989. a saakidest saagiga mullast eemaldatavate toitainete määramise eesmärgil. Katseaastate sademete ja temperatuuri andmed vegetatsiooniperioodil on toodud joonistel 1–4.

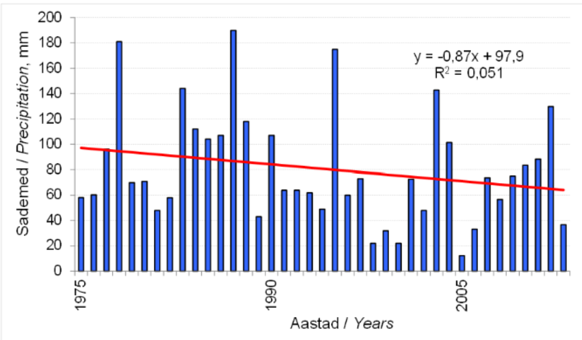
Katseandmete töötlemisel kasutati dispersioon ja regressioonanalüüsi.



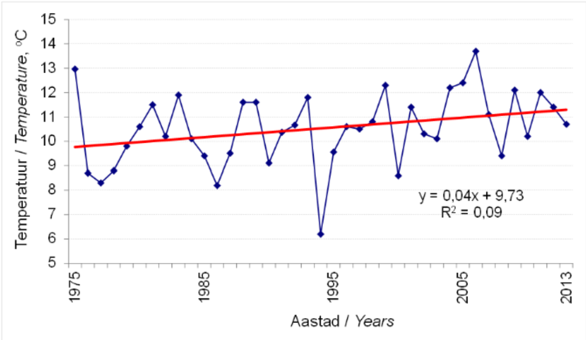
Joonis 1. Sademed ja nende trend vegetatsiooniperioodil aastatel 1976–2012 Kuusikul
Figure 1. *Precipitation and their trends in vegetation periods in years 1976–2012 in Kuusiku*



Joonis 2. Õhutemperatuurid ja nende trend vegetatsiooniperioodil aastatel 1976–2012 Kuusikul
Figure 2. *The temperatures and their trends in vegetation periods in years 1976–2012 in Kuusiku*



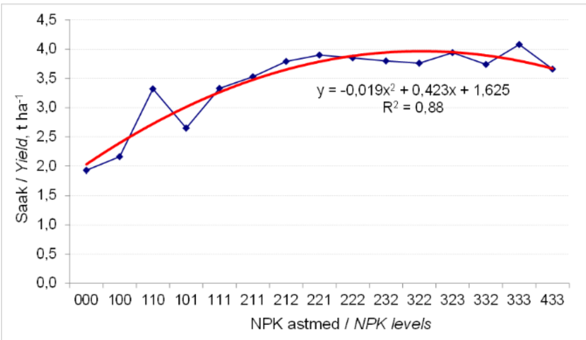
Joonis 3. Septembrikuu sademed rukki kasvu algul katseperioodil Kuusikul
Figure 3. *The precipitation in September on different years during the trial periood in Kuusiku*



Joonis 4. Septembrikuu temperatuurid rukki kasvu algul katseperioodil Kuusikul
Figure 4. *The temperatures in September on different years during the trial periood in Kuusiku*

Tulemused ja arutelu

Pikaajalise katse talirukki terasaagi tulemuste analüüsist selgus et, väetamata mullalt (joonis 5) saadi 19 saagiaasta keskmisena teri 1,9 t ha^{-1} (PD05 0,35). Väetiste kasutamisel saadi $N_{135}P_{39}K_{90}$-variandi mullalt aga suurim 19 aasta keskmine terasaak, 4,1 t ha^{-1} (PD05 0,44).



Joonis 5. Talirukki saagikus sõltuvalt NPK-väetustasemest
Figure 5. *The productivity of winter rye depending on NPK fertilization level*

Sõnniku mõju koos mineraalväetistega külvikorras rukki terasaagile oli tagasihoidlik (tabel 1), kuna sõnnik anti külvikorra esimesele kultuurile kartulile ja rukkile kui külvikorras viimasele kultuurile sõnniku järelmõju enam ei ulatunud.

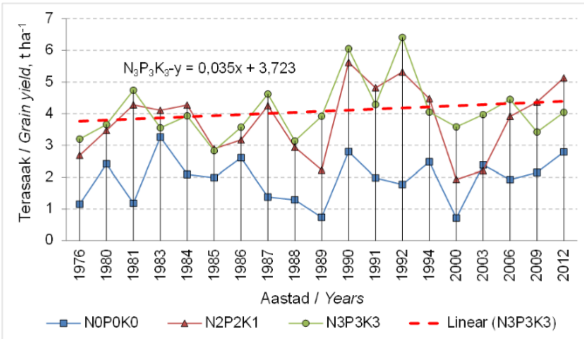
Tabel 1. Mineraalväetiste ja sõnniku koosmõju talirukki terasaagile (t ha^{-1}) külvikorras
Table 1.*The effect of mineral fertilizers and farmyard manure on grain yield of winter rye (t ha^{-1})*

NPK aste NPK *level*	NPK	NPK+30*	NPK+60	PD *LSD 95%*
222 ($N_{90}P_{26}K_{60}$)	3,9	3,8	3,9	0,14
322 ($N_{135}P_{26}K_{60}$)	3,8	4,0	4,0	0,29
433 ($N_{180}P_{39}K_{90}$)	3,7	3,9	3,8	0,15
PD *LSD 95%*	0,24	0,30	0,15	

* – mineraalväetis koos sõnnikuga 30 ja 60 t ha^{-1}

Sõnniku järelmõju efektiivsust kahandas ilmselt ka külvikorras kasvanud põldheina (timut + ristik) mõjul märgatavalt suurenenud mulla huumusesisaldus, mis moodustas 3,0–3,3%. Tahkesõnniku positiivne järelmõju avaldus rukki terasaagile põhimõtteliselt sama külvikorraga katses, ainult põldheina kooslusest puudus ristik, kuid oluliselt huumusvaesemal (1,5–1,6%) leetunud saviliivmullal (Kärblane jt, 1999). Sõnniku kasutamisel külvikorras on mitmeid kasulikke omadusi, mis teatud tingimustes võivad oluliselt parandada saagikust ja saagi kvaliteeti. Leedu uurijad (Lisova jt, 1996) on leidnud, et sõnniku kasutamine külvikorras suurendas 2–3,5 korda rukki vastupanuvõimet haigestuda seenhaigustesse.

Väetistest enam mõjutas saagikust aga ilmastik. Rukis on teraviljadest ka parima saagistabiilsusega teravili: Saksamaal Berlin-Dahlemi katsepunktis oli 35 aasta andmetel talirukki saagi varieeruvuskoefitsient 17% (Chmielewski, Köhn, 1999). Joonisel 6 on toodud rukki saagikuse rukki kerge tõusuga ja suure varieeruvusega trend eri väetustasemetel.



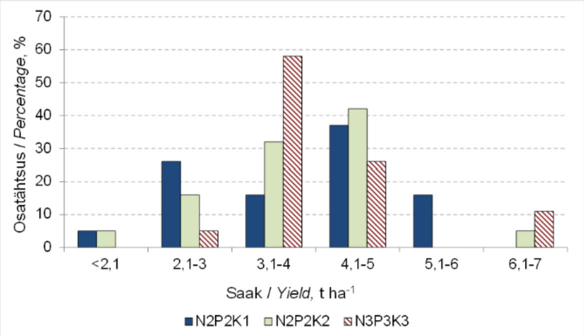
Joonis 6. Talirukki terasaagi trendid katseperioodil
Figure 6. *The trends of winter rye grain yield during the trial periood*

Saagikuse tõusu võib seletada ilmselt rukkile jt taliteraviljadele järjest soodsamaks muutuva ilmastiku mõjuga katse hilisemal perioodil. Rukki terasaak varieerus väetamata foonil vahemikus 0,7–3,3 t ha^{-1}, mis kinnitab rukki suur võimet omastada toitaineid soodsate ilmastikutingimuste korral ka toitainetevaesest mullast. Soodsates ilmastikutingimustes on samuti ka mulla mineraliseerumine ja sealt toitainete vabanemine intensiivsem. NPK väetustasemete 221 ja 333 variantide saagid varieerusid vastavalt vahemikes 1,9–5,6 ja 2,8–6,4 t ha^{-1} mullast.

Lisaks ilmastikutingimustele mõjutab saagikuse varieeruvust ka väetamine. Väetusvariantide $N_{90}P_{26}K_{30}$; $N_{90}P_{26}K_{60}$ ja $N_{135}P_{39}K_{90}$, (joonisel 7 vastavalt 221, 222, 333), terasaagid olid katseperioodil valdavalt vahemikus 3–5 t ha^{-1}. Sagedamini esines saagikust 3–4 t ha^{-1} (osatähtsus 58%) väetusvariandi $N_{135}P_{39}K_{90}$ (333) puhul. Rukis 'Vambo' saagipotentsiaalile, 5500–6000 kg ha^{-1}, (Tupits jt, 1999) vastav terasaak, 6,1–6,4 t ha^{-1}, saadi katseperioodil ainult kahel aastal. Rekordsaagiks on teadaolevalt sort 'Vambo' andnud 8 t teri hektarilt (Tupits, 2012).

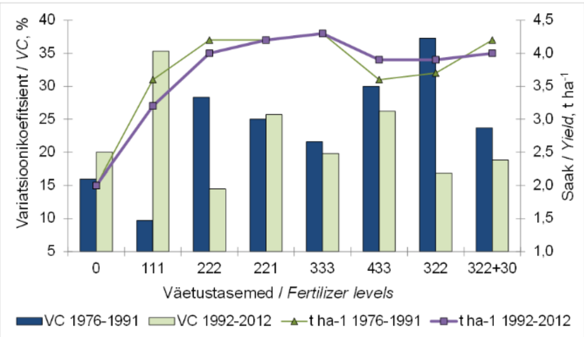
Ilmastiku mõju saagikusele mõjutab ka kasutatud väetiste efektiivsust. Väetamine mõjutab aga omakorda saagistabiilsust. Maksimaalse saagi andnud variandis $N_{135}P_{39}K_{90}$ (NPK aste 333) kasutati NPK väetisi aga 264 kg ha^{-1} ja 1 kg NPK-väetisega saadi 16 kg teri.

Väetiste kasutuse efektiivsuselt osutus tulemuslikumaks väetusvariant $N_{90}P_{26}K_{30}$ (ja juhul kui soovitakse põhk põllult eemaldada, siis suurema koguse K eemaldumise tõttu arvestuslikult $N_{90}P_{26}K_{60}$), mille puhul kasutati väetisi tegevaines kokku 146 kg ha^{-1} ja 1 kg väetisega saadi 27 kg teri. Väetusvariandi $N_{90}P_{26}K_{30}$ (aste 221) terasaak jäi suurimast, $N_{135}P_{39}K_{90}$-variandi hektarisaagist ainult 200 kg võrra väiksemaks. Nelja tonni terasaagiga eemaldati toiteelemente $N_{48}P_{14}K_{20}$ (koos põhuga $N_{88}P_{19}K_{72}$).



Joonis 7. Talirukki eri saagikuste osakaal katseperioodil sõltuvalt väetustasemest
Figure 7. *The share of rye yield (in %) depending of fertilization level*

Vaadeldes aastamõju eri väetusvariantide saagikuse stabiilsusele (joonis 8), näeme et kogu katseperioodi rukki kõige väiksem saagikuse varieerumine, keskmine variatsioonikoefitsient 18, oli väetamata variandil. Ilmselt on see tingitud väetamata variandi madal saagikus, kus saakide omavaheline erinevus on aastati väiksem.



Joonis 8. Talirukki saagikuse varieeruvus sõltuvalt väetustasemest, variandi keskmine saak katse eri etappidel (PD 95%: VC-1976–1991 – 7,1; VC-1992–2012 – 5,6; saak – 0,6)
Figure 8. *The variability of yield depending on fertilization levels, average variant yield in different stanges of trial (LDS 95%: VC-1976–1991 – 7.1; VC-1992–2012 – 5.6; yield – 0.6)*

Järgnes väetusvariant $N_{135}P_{39}K_{90}$ (333), kus saadi ka suurim keskmine terasaak. Optimaalselt väetatud variandi terasaakide katseperioodi keskmine varieeruvus oli 21%. Saagikuse varieeruvust esines kõige enam madalamate väetustasemete (111, 222, 322) korral, vastavalt 35, 28 ja 37%. Teadaolevalt on taimetoitainete rikkamal mullal kasvanud taimed suurema vastupanuvõimega ilmastiku mõjutustele. Mitme eri muldadel läbiviidud katsete andmetel on olnud põuatingimustes väetatud katselappide saagikadu väiksem kui väetamata katselappidel (Hannolainen jt, 2003). Ka antud katses ilmnes väetamata ja vähese väetiste kasutamise korral saagikuse suurem varieeruvus katse hilisemal perioodil (1992–2012), mil esines rohkem põuda, mis raskendas toitainete omastamist taimede poolt. Seega vastukaaluks suurematele kulutustele väetistele ja paremale saagistabiilsusele väheneb madala saagikusega aastate osatähtsus ning koos sellega kaasnev tootmiskulu (Loko, Koik, 2006).

Teada on, et peamiseks saaki limiteerivaks faktoriks on vesi. E. Haller (1969) on oma uurimistöös märkinud, et põllukultuuride saagikus sõltub juba idanemisaegsest vee-, õhu- ja toiterežiimist. Seega talirukki terasaagile on määravaks septembrikuu ilmastikutingimused, mis mõjutavad taimede algarengut. Rukki hea saagi eelduseks on soe ja päikesepaisteline kasvualgus algus ja jahe talvitumisjärgne vegetatsiooniperiood (Chemielewski, Köhn, 1999). Pikaajalise vaatlustulemuste põhjal on teada et, rukis vajab saagi moodustamiseks vegetatsiooniperioodi algusest kuni saagi koristuseni üle +5°C soojust 994 kraadi ja sademeid 255 mm (Tupits, Sooväli, 2007). Taimejuurte levikust sõltub veekättesaadavus. Teraviljad omastavad mullast vett ja toitaineid idujuurtega ja alates võrsumisest ka lisajuurtega. Taimed jõulise ja ulatusliku juurestikuga omastavad saagi moodustamiseks vett ja toitaineid suuremalt pinnalt ja on ühtlasi vastupidavamad ilmastikuoludele (Haller, 1969; Merrill jt, 2002; Dempewolf jt, 2014).

Kuigi sademete ja temperatuuri trend oli kogu vegetatsiooniperioodi keskmisena (joonised 1 ja 2) tõusev ehk ilmad on järjest sajusemaks ja soojemaks muutunud, siis septembrikuu (joonised 3 ja 4) sademete hulk oli langeva ning temperatuur tõusva trendiga ja väga varieeruvad. Sademeid oli septembrikuus katse esimese poolel (1975–1991) keskmiselt 107 mm ja katseperioodi teisel, hilisemal poolel 70 mm ning temperatuur vastavalt 10,0 ja 10,8°C. Teraviljadele soodsate ja ebasoodsate ilmastikutingimuste analüüsitulemustest ilmnes, et talivilju ohustab septembrikuus liigniiskus. Keskmine 40 aasta hüdrotermiline koefitsient (HTK) oli 2,9. Kuusiku katseala viimased 20 aastat olid kuivemad, keskmine HTK oli vähenenud 2,0ni e parasniiskeni (Loide, 2015) e siis ilmastikutingimused on paranenud viimasel ajal rukki kasvu algfaasis Kuusiku katsealal.

Käesolevaks ajaks on sort 'Vambo' juba taandumas uute sortide ees, mis on veelgi suurema saagikusega ja parema kvaliteediga, nagu näiteks suurem langemisarv ja mahukaal (Riiklike…, 2014). Saagikuselt ei jää rukis teistest teraviljadest maha – Eestis on rukki rekordsaagiks seni saadud 9,7 t ha^{-1} 2012. aastal Viljandimaal (Ameerikas, 2014). Talirukki mitmetele headele omadustele vaatamata moodustab rukis ainult 5% vabariigi teravilja külvipinnast, oder ja nisu vastavalt 40 ja 46% (Eesti…, 2014). Katseandmetest on selgunud, et hea eelviljana suurendas rukki kasvatamine vaheldumisi suviodraga teravilja keskmist saagikust odra monokultuuris kasvanud odraga võrreldes 10–13% (Häusler, Hannolainen, 2006). Peale tervisliku toiduvilja on rukkil küllalt palju arenguruumi ka teistes kasutusvaldkondades, mis suurendaks nõudlust rukki järele ja rukki külvipind võiks oluliselt laieneda. Kuigi rukist ei ole peetud sageli sobivaks teraviljaks kasutamiseks loomakasvatuses, kasutatakse rukist loomakasvatuses paljudes riikides haljassöödana, segus teiste teraviljadega nuumveiste ja -sigade söödaratsioonis (Boros, 2007).

Järeldused

Käesoleva uurimistöötulemusi kokkuvõttes võib öelda, et talirukis kui vähenõudlik teraviljakultuur, on ka hea saagi ja saagistabiilsusega küllaldase väetamise korral. Parima keskmise saagikuse tagas väetusvariant, kus kasutati mineraalväetisi tasemel $N_{135}P_{39}K_{90}$ ja 19 aasta talirukki 'Vambo' keskmine terasaak oli 4,1 t ha^{-1} ning väetamata variandi mullalt 1,9 t ha^{-1}. Väetusvariandi $N_{135}P_{39}K_{90}$ kõige suurema, 58% osatähtsusega, saagikus oli 3–4 t ha^{-1}, üle 6 t ha^{-1} terasaakisid esines katseperioodil ainult kahel aastal, osatähtsus 11%. Katseperioodi teise poole ilmastikutingimused olid taimede kasvuks ja arenguks soodsamad, mis samuti mõjutasid positiivselt rukki saagikust ja saagistabiilsust. Tulemustele lisab väärtust veel see, et need on saadud ühe ja sama sordiga ning puudub eri sortidest tulenev segav faktor. Mineraalväetiste ja sõnniku koosmõju rukki terasaagile jäi tagasihoidlikuks, kuna sõnnik anti külvikorra esimesele kultuurile (kartulile) ja rukkile kui külvikorras viimasele kultuurile sõnniku mõju enam ei ulatunud.

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Kasutatud kirjandus

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The productivity and yield stability of winter rye variety 'Vambo' in long term NPK fertilization trial on calcaric cambisol

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Summary

Traditionally rye is the culture which productivity has been the most stable and resistant to the weather conditions. Using the variety selection the diploid rye variety 'Vambo' was developed, which differs a lot from 'Sangaste' type of rye by straw and ear size as well as productivity. Current research was based on long term crop rotation NPK-fertilization trial from years 1975–2012, which was conducted by PhD A. Piho in years 1965–1966 in North Estonia Kuusiku on loamy *Calcaric Gambisol*.

Trial is established as six year crop rotation (potato-late maturing spring barley-undersown early maturing spring barley-first year grass clover mixture-second year grass clover mixture-rye). The traditional agro-technical measures were applied like ploughing, chemical weed control and plant protection measures. The trial contains 21 combined NPK mineral and organic (farmyard manure) variants. NPK-fertilizers (measured as elements kg ha^{-1}) different levels: level 000=$N_0P_0K_0$; 111= $N_{45}P_{13}K_{30}$; 222=$N_{90}P_{26}K_{60}$; 333= $N_{135}P_{39}K_{90}$; 433=$N_{180}P_{39}K_{90}$; combined variants of mineral and organic fertilisers at two levels were used: NPK+30 and +60 t ha^{-1}.

On the average of 19 years the yield of rye from unfertilised plots was 1.9 t ha^{-1}, by using of mineral fertilizers in level 3 ($N_{135}P_{39}K_{90}$) the yield was 4.1 t ha^{-1}. The effect of farmyard manure combined with mineral fertilizers was modest (Table 1) as the organic fertilizer was applied to the first culture in crop rotation (potato) and the last culture rye didn't get any benefit from that.

The weather conditions had greater impact on yield as fertilization. Different fertilizing levels (Figure 6) have had positive effect on rye productivity, but the variability was remarkable. The best stability of yields was recorded in fertilization level 333 ($N_{135}P_{39}K_{90}$) where the average yield levels of 3–5 t ha^{-1} was 84%. In the same time the fertilization levels 222 ($N_{90}P_{26}K_{60}$) and 221 ($N_{90}P_{26}K_{30}$) gave the same productivity 74 and 53% accordingly. Compared to the smaller rates of fertilization the plots with higher fertilization rates (NPK 222 and higher) resulted in smaller variability in yields (Figure 8) which decreased even more in the second half of the trial period (1992–2012). The plots getting lower amount of fertilizers the variability in yields was increasing.

To conclude the results of the investigation we can say that winter rye as the undemanding culture has also good yield potential and stability if the fertilization level is satisfying. The best yield was obtained from the plot where mineral fertilizers $N_{135}P_{39}K_{90}$ were used. The weather conditions in the second half of whole trial period were more favourable for plants growth and development, so it influenced positively the rye yield and its stability. The effect of farmyard manure combined with mineral fertilizers was most as the organic fertilizer was applied to the first culture in crop rotation (potato) and the last culture rye didn't get any benefit from that.

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TERMOFIILSETE KAMPÜLOBAKTERITE LEVIMUS, ARVUKUS JA RAVIMTUNDLIKKUS VÄRSKES KANALIHAS EESTI JAEMÜÜGI TASANDIL

THE PREVALENCE, COUNTS AND ANTIMICROBIAL SUSCEPTIBILITY OF THERMOPHILIC *CAMPYLOBACTER* SPP. IN FRESH CHICKEN MEAT AT ESTONIAN RETAIL LEVEL

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ABSTRACT. Thermophilic *Campylobacter* spp. are one of the most common cause of acute gastroenteritis in European Union and the illness is frequently associated with the consumption of chicken meat. The aim of the present study is to give an overview about the prevalence, counts and antimicrobial susceptibility of *Campylobacter* spp. in fresh chicken meat at the Estonian retail level. *Campylobacter* spp. was isolated in 77 (35%) of 220 meat samples. Altogether, 24 (20.3%) of Estonian origin, 41 (50%) of Lithuanian origin and 12 (60%) of Latvian origin chicken fresh meat samples were positive for *Campylobacter* at Estonian retail level. The highest counts of *Campylobacter* spp., on average 2600 CFU g^{-1}, were detected in the chicken meat of Lithuanian origin followed by on average 1600 CFU g^{-1} and 660 CFU g^{-1} in samples of Latvian and Estonian origin, respectively. The seasonal peak of *Campylobacter* contamination was between June and September. A total of 36 isolates (36.7%) of 98 were susceptible to all the tested antimicrobials. The highest proportion of isolates (41 isolates, 41.8%) was resistant to fluoroquinolones. Multiresistance was detected in 5 (5.1%) isolates. In conclusion, compared to fresh chicken meat products of Lithuanian and Latvian origin, the prevalence, counts and antimicrobial resistance of *Campylobacter* spp. in fresh chicken meat of Estonian origin were lower. Therefore we suppose that the risk of occurrence of *Campylobacter* human infection by consuming domestic chicken meat is lower than by consuming imported chicken meat.

Sissejuhatus

Termofiilsed kampülobakterid on inimestel sagedased akuutsete gastroenteriitide põhjustajad paljudes riikides (EFSA, 2014). Üldjuhul on tegemist kergekujulise haigusega, mille põhitunnuseks on kõhulahtisus ja palavik, kuid tõsisematel juhtudel võib sellest tulenevalt esineda ka artriiti, bakterieemiat, meningiiti, endokardiiti, jne. Rahvatervise seisukohalt on *C. jejuni* ja *C. coli* kui võimalikud haigestumise põhjustajad kampülobakterite liikidest kõige olulisemad. Kampülobakterenteriiti seostatakse kõige enam kampülobakteritega saastunud linnuliha, toorpiima ja joogivee tarbimisega (Calciati jt, 2012; Taylor jt, 2013; Jacopanec jt, 2008; Mazick jt, 2006). Kirjanduse andmetel omab värske kanaliha kõige suuremat tähtsust kampülobakterenteriidi tekkes ning sellest tingituna on linnuliha adekvaatne kontroll kampülobakterenteriidi ennetamises üks kõige olulisemaid rahvatervishoiu strateegiaid (Roasto jt, 2015; Rosenquist jt, 2009; Wingstrand jt, 2006). Linnuliha saastumine termofiilsete kampülobakteritega osutab reeglina faktile, et haigustekitajatest on saastunud nii toidu algtootmise ja töötlemise tasand kui ka sellele järgnevad käitlemise etapid ehk kogu kanaliha tootmise ahel (Ma jt, 2014; Meremäe jt, 2010). Farmi tasandil on perekonna *Campylobacter* liigid nii sise- kui väliskeskkonnas laialdaselt levinud, mistõttu võivad nii linnud kui loomad olla kampülobakterite asümptomaatilisteks kandjateks. Kampülobakterite kolonisatsioon kanadel levib enamasti nn horisontaalse ülekande kaudu, näiteks sööda, joogivee, näriliste, putukate ja inimtegevuse teel (Saleha, 2004). Tapamaja tasandil on reeglina kampülobakterite allikaks tapalindude soolesisaldis, mis võib algtöötlemise käigus sattuda rümbalt rümbale või rümbalt töövahenditele ja seadmetele (Ma jt, 2014; Stern ja Robach, 2003). Nii võib linnuliha saastumine kampülobakteritega aset leida nii tapamaja tasandil rümpade käitlemisel kui edasisel liha töötlemisel. Kampülobakterite leviku ennetamiseks ning saastumise olemasolul nende arvukuse vähendamiseks on võimalik rakendada väga erinevaid meetmeid alates elementaarsete bioohutusmeetmete rakendamisest farmi tasandil, hügieeninõuete täitmisest kõikides toidu tootmise ja käitlemise etappides kuni tehnoloogiliste lahendusteni tapamaja tasandil, näiteks rümpade efektiivse õhkjahutamise kasutamine jne. (Roasto jt, 2015; Rosenquist jt, 2009). Siiski võib kampülobakterite ülekanne toimuda ka jaemüügi tasandil ristsaastumise kaudu, mistõttu täies ulatuses kampülobaktererid kanaliha tootmise ahelas alati elimineerida ei õnnestu. Värske kanaliha saastumise korral kampülobakteritega on rahvatervise probleemiks ka antibiootikumidele resistentsed kampülobakterite tüved (Ma jt, 2014; Roasto jt, 2007). Resistentsete bakterite esinemine ja ringlemine toidu tootmise ahelas ning jõudmine tarbijani võib kujutada tõsist ohtu inimese tervisele. Sellisel juhul võib haigestunud inimese ravi eesmärgipärase antibiootikumiga tavapärasest pikeneda või isegi ebaõnnestuda (Travers, Barza, 2002). Bakterite resistentsuse (sh multiresistentsuse) esinemine kanaliha tootmise ahelas peegeldab otseselt antibiootikumide laialdast kasutamist farmi tasandil kas profülaktilistel või ravi eesmärkidel pikema perioodi vältel (Ma jt, 2014; Smith jt, 2007). Seepärast teadusuuringud, mis aitavad välja selgitada nii kampülobakterite levimust kui antibiootikumresistentsust toidu tootmise ahelas, äärmiselt vajalikud. Käesoleva töö eesmärgiks on anda ülevaade aastatel 2012–2014 teostatud termofiilsete kampülobakterite teadusuuringutest Eestis, et hinnata *Campylobacter* spp. levimust, arvukust ja tundlikkust antibiootikumidele värskes kanalihas ning anda värske kanalihaga seonduvalt kvalitatiivne riskihinnang.

Materjal ja metoodika

Campylobacter spp. levimus ja arvukus

Uurimustöös analüüsiti 220 nahka sisaldavat värske kanaliha proovi, mis koguti Eesti jaemüügi tasandil aastal 2012. Kogutud proovidest moodustasid Eesti, Läti ja Leedu tooted vastavalt 53,6%, 37,3% ja 9,1%. Nii Eesti kui Leedu päritolu tooteid koguti aastaringselt igal kuul, kuid Läti päritolu tooted olid uurimisperioodil turul kättesaadavad vaid vahemikus september kuni detsember 2012. Kogutud proovid olid tootjapoolsetes originaalpakendites, mis välistas proovide transpordist ja jaekaubandusest tingitud ristsaastumise. Proovide kogumisel oli eeltingimuseks kahjustamata pakend ning proovide kiire analüüsilaborisse toimetamine. Proovid toimetati laborisse külmakastides.

Termofiilsete kampülobakterite tuvastamiseks värskes kanalihas kasutati EVS-EN ISO 10272-1:2006 meetodit ning arvukuse loendamiseks ISO/TS 10272-2:2006 meetodit, mida on põhjalikumalt kirjeldatud Mäesaar jt (2015; 2014) poolt. Lühidalt, 10 grammi kanaliha proovi asetati steriilsesse Stomacheri kilekotti, millesse lisati 90 ml steriilset puhverdatud peptoonvett. Seejärel töödeldi proove 1 minuti jooksul Stomacher segistis. Edasiselt kanti 0,1 ml 10^{-1} ja 10^{-2} lahjendust mCCDA agariga (modified CCDA, Charcoal Cefoperazone Deoxycholate Agar, Oxoid) Petri tassidele ja inkubeeriti mikroaeroobsetes tingimustes (CampyGenTM, Oxoid) 44–48 tundi temperatuuridel 41,5 ± 0,5ºC. Paralleelselt eeltoodule kanti 10 g lihaproovi ka steriilsesse Shoti söötmepudelisse, kuhu lisati 90 ml Boltoni rikastuspuljongit (Oxoid, Basingstoke, Hampshire, England). Neid proove inkubeeriti mikroaeroobsetes tingimustes 4–6 tundi temperatuuril 37°C ± 1ºC juures ja 44 ± 4 tundi temperatuuril 41,5 ± 0,5ºC juures. Seejärel kanti 10 µl rikastuspuljongit mCCDA agarile ja inkubeeriti mikroaeroobsetes tingimustes (CampyGenTM, Oxoid) 44–48 tundi temperatuuril 41,5 ± 0,5ºC.

Vastavalt ISO standardile, kampülobakterite tüüpilised kolooniad mCCDA agaril külvati edasi puhaskultuuri saamiseks ja tõestuskatsete (kampülobakterite liikuvuse määramine, Gram'i järgi värvimine, biokeemilised testid) tegemiseks Columbia vereagarile (Oxoid), mida inkubeeriti 24 tundi temperatuuril 41,5 ± 0,5ºC. Puhaskultuur säilitati glütserooli puljongis (15% [v/v] glütserooli 1%-ses [w/v-mahukaal] proteoospeptoonis) temperatuuril –82°C. Katsed viidi läbi Eesti Maaülikooli toiduhügieeni osakonnas.

Campylobacter spp. liigilise kuuluvuse määramine

Campylobacter jejuni, *C. coli*, *C. lari*, *C. upsaliensis*'e, ja *C. fetus* subsp. *fetus*'e identifitseerimiseks ja eristamiseks kasutati konventsionaalset PCR-meetodit, mida on põhjalikult kirjeldatud Wang jt (2002) poolt.

Campylobacter tüvede antibiootikumidele tundlikkus

Campylobacter tüvede antibiootikumi tundlikkuse uuringusse kaasati 98 isolaati, millest 36 (36,7%) olid Eesti, 46 (46,9%) Leedu ja 16 (16,3%) Läti päritolu. Tegemist oli kanalihalt (n=517) isoleeritud tüvedega, mis koguti 2012. aastal nii Eesti Maaülikooli toiduhügieeni osakonnas läbi viidud uuringu kui ka Veterinaar- ja Toidulaboratooriumi riikliku monitooringu käigus. Termofiilsete kampülobakterite tuvastamiseks kasutati EVS-EN ISO 10272-1:2006 meetodit. Kogutud tüvede (n=126) antibiootikumide tundlikkuse määramisel kasutati minimaalse inhibeeriva kontsentratsiooni määramise VetMIC™-testi (National Veterinary Institute; Uppsala, Sweden), mida on põhjalikumalt kirjeldatud meie teadusuuringus Mäesaar jt (2015) poolt. Uuringud teostati 2013. ja 2014. aastal. Minimaalse inhibeeriva kontsentratsiooni (MIC) määramiseks testiti *Campylobacter* isolaate erütromütsiini, tsiprofloksatsiini, tetratsükliini, streptomütsiini, gentamütsiini ja nalidiksiinhappe suhtes. Selleks võeti aasatäis (1 µl) Columbia vereagaril (Oxoid) välja kasvanud *Campylobacter* puhaskultuuri ning kanti edasi 10 ml katioonidega rikastatud ja 5% verd sisaldavasse Mueller-Hinton (CAMHB) puljongisse (Oxoid; Basingstoke, Hampshire, England) ning inkubeeriti temperatuuril 37 ± 1°C 20 tundi. Tulemuseks saadi kasvu tihedus ligikaudu 10^8 PMÜ ml^{-1}. Pärast inkubeerimist kanti lahjendatud baktersuspensioon VetMIC™ mikroplaadi aukudesse. Mikroplaate inkubeeriti temperatuuril 37 ± 1ºC 40–48 tundi ning seejärel loeti tulemused. Isolaatide antibiootikumidele tundlikkuse hindamisel võeti aluseks The European Committee on Antimicrobial Susceptibility Testing (EUCAST) soovitusi (2013[a,b]). *C. jejuni* oli antibiootikumidele resistentne, kui MIC väärtused olid järgmised: erütromütsiin >4 µg/ml, tsiprofloksatsiin >1 µg/ml, tetratsükliin >2 µg/ml, streptomütsiin >2 µg/ml, nalidiksiinhape >16 µg/ml ja gentamütsiin >1 µg/ml. *C. coli* oli antibiootikumidele resistentne, kui MIC väärtused olid järgmised: erütromütsiin >16 µg/ml, tsiprofloksatsiin >1 µg/ml, tetratsükliin >2 µg/ml, streptomütsiin >4 µg/ml, nalidiksiinhape >32 µg/ml ja gentamütsiin >2 µg/ml.

Statistiline analüüs

Andmete töötlemisel kasutati MS Excel 2010 tarkvara (Microsoft Corporation; Redmond, WA, USA) ja andmete statistiline analüüs tehti tarkvarapaketiga R. Kampülobakterite levimus- ja arvukusnäitajate statistilisel töötlemisel kasutati Kruskal-Wallis testi ja Hii-ruut testi. Kampülobakterite antibiootikumidele tundlikkuse andmete töötlemisel kasutati statistikaprogrammi The Statistical Package for Social Sciences 13.0 (SPSS Inc.; Chicago, IL, USA).

Tulemused ja arutelu

***Campylobacter* spp. levimus ja arvukus**

Eesti Teadusagentuuri grandiprojekti (nr 9315) ja Põllumajandusministeeriumi rakendusuuringute projekti (leping nr T13057VLTH) raames uuriti ühtekokku 220 värske kanaliha proovi. Uurimustulemused näitasid, et *Campylobacter* spp. isoleeriti ühtekokku 77 (35%) Eesti jaemüügi tasandil kogutud värske kanaliha proovist (tabel 1). Nende hulgas oli Eesti päritolu *Campylobacter*-positiivseid kanaliha proove 24 (20,3%), Leedu päritolu 41 (50%) ja Läti päritolu proove 12 (60%). Sellest järeldub, et päritolu arvestades oli termofiilsete kampülobakterite kontaminatsioon 2012. aastal Eesti jaemüügi tasandil kogutud kanaliha toodetes erinev. Võrdluseks, aastatel 2000–2010 Eestis läbi viidud *Campylobacter* spp. levimusuuringus (Roasto jt, 2011) oli 1965 liha proovidest *Campylobacter*-positiivseid kokku 221 (11,3%), mis on oluliselt madalam näitaja, kui 2012. aastal. Siiski ka aastatel 2000–2010 esines kampülobakterite kontaminatsioonimäärades suuri varieeruvusi aastate lõikes. Meie varasemates uuringutes (Roasto jt, 2011; Meremäe jt, 2010) oli aastatel 2000 ja 2003–2004 kampülobakterite esinemine kanalihaproovides vastavalt 35,6%, 28,8% ja 29,8%, kuid ajavahemikus 2005–2010 varieerus *Campylobacter*-positiivsete proovide osakaal vahemikus 2,2–8,3%. Juhtudel, kus uurimusmaterjaliks on olnud nahaga linnulihatooted, on alust eeldada ka *Campylobacter*-positiivsete proovide suuremat osakaalu. Seda kinnitab ka Soomes läbi viidud uuring, kus kampülobakterite levimus nahaga linnuliha toodetes oli oluliselt kõrgem (30,4%) kui nahata tükilihas (9,4%) või rinnafilees (4,7%) (Katzav jt, 2008). Kirjanduse andmete põhjal võib siiski tõdeda, et võrreldes Eestiga on teistes riikides (näiteks Lätis, Leedus, Soomes, Rootsis) *Campylobacter* spp. levimus toores linnulihas oluliselt kõrgem varieerudes 42,2% kuni 56,3% (Kovalenko jt, 2013; Bunevičienė jt, 2010; Suzuki, Yamamoto, 2009). Ka käesolevas uuringus selgus, et Eesti turul müügil olevad Leedu ja Läti päritolu kanaliha importtooted olid Eesti toodetest enam saastunud ehk *Campylobacter*-positiivsete toodete proportsioon oli vastavalt 50% ja 60%. Andmete statistilise töötlemise tulemusel saame väita, et importtooted olid oluliselt ($p < 0{,}001$) rohkem saastunud termofiilsete kampülobakteritega kui Eesti päritolu tooted (20,3%). Sarnasele järeldusele on jõutud ka meie varasemates teadustöödes (Roasto jt, 2015; 2011).

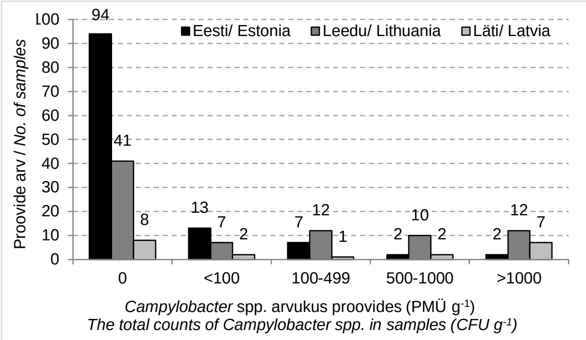
Tabel 1. Kampülobakterite levimus ja arvukus värske kanaliha proovides (Roasto jt, 2015; Mäesaar jt, 2014)
Table 1. *The prevalence and total counts of* Campylobacter *spp. in fresh chicken meat samples (Roasto* et al*., 2015; Mäesaar* et al*., 2014)*

Päritolumaa *Origin of country*	Positiivsete proovide arv / proovide üldarv (% positiivseid) *Number of positive/total number of samples (% positive)*	Positiivsete proovide usaldusvahemik (95% CI) *95% confidence intervals of positive samples*	Keskmine bakterite arvukus proovides (log_{10}PMÜ g^{-1}) *The average number of bacteria in samples ($log_{10}CFU\ g^{-1}$)*	Usaldusvahemik arvukuses (95% CI) *95% confidence intervals in total counts*
Eesti/*Estonia*	24/118 (20,3)	14%–29%	660 (2,8)	190–1120
Leedu/*Lithuania*	41/82 (50)	39%–61%	1600 (3,2)	372–2814
Läti/*Latvia*	12/20 (60)	39%–78%	2600 (3,4)	919–4261
Kokku/*Total*	77/220 (35)	29%–42%	1600 (3,2)	782–2390

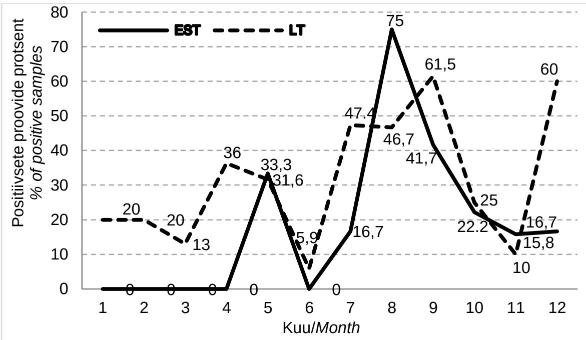
Kampülobakterite levimusest on veelgi olulisem kampülobakterite arvukus tootes, millest otseselt sõltub, kui suurt riski kujutab potentsiaalselt saastunud toote tarbimine inimese tervisele. Meie uuringus selgus, et kampülobakterite arvukus värske kanaliha proovides oli keskmiselt 1600 PMÜ/g^{-1} (tabel 1), varieerudes vahemikus 782–2390 bakterit/grammis. Kõrgeim kampülobakterite arvukus (2600 PMÜ g^{-1}) oli loendatud Läti päritolu proovides, millele järgnesid Leedu päritolu tooted, keskmiselt 1600 PMÜ g^{-1}. Eesti päritolu kanaliha toodetes oli keskmine kampülobakterite arvukus 660 PMÜ g^{-1}, mis oli oluliselt ($p < 0{,}001$) madalam kui importtoodetes. Inimese haigestumise esilekutsumiseks arvatakse piisav olema ligikaudu 500 kampülobakteri esinemine tootes (Keener jt, 2004), sõltudes bakteritüve virulentsusest, inimese vastupanuvõimest jne. Siiski EFSA (2013; 2011) andmetel on risk inimese tervisele suurim kampülobakterite arvukuse esinemisel >1000 PMÜ g^{-1} toote kohta.

Joonis 1 annab ülevaate värske kanaliha *Campylobacter* spp. loendamise tulemustest. Tulemustes selgus, et ühtekokku 143 proovis (65% proovidest) kampülobaktereid ei tuvastatud, kuna proovid andsid nii kampülobakterite tuvastamisel kui loendamisel negatiivse tulemuse. Kokku 22 (10%) värske kanaliha proovi sisaldas kampülobaktereid vähem kui 100 PMÜ g^{-1} (kajastades negatiivse loendamise, kuid kampülobakterite suhtes positiivse tuvastamise tulemust). Siiski, 20 (9,1%) proovi sisaldas kampülobaktereid vahemikus 100–499 PMÜ g^{-1} ja 14 (6,4%) proovi vahemikus 500–1000 PMÜ g^{-1}. Rohkem kui 1000 PMÜ g^{-1} sisaldas 21 (35%) proovi, neist 2 (1,7%) Eesti, 12 (14,6%) Leedu ja 7 (35,0%) Läti päritolu proovi. Kuigi varasemalt on Leedus teostatud uuring (Bunevičienė jt, 2010) leidnud kampülobakterite keskmiseks arvukuseks 110 PMÜ g^{-1}, siis meie uuring kinnitas oluliselt kõrgemaid kontaminatsioonimäärasid Leedu päritolu toore linnuliha proovide hulgas. Käesolevas uuringus leiti ka statistiliselt oluline erinevus kampülobakterite levimusnäitajates ja arvukuses nii Eesti ja Leedu ($p < 0,001$) kui ka Eesti ja Läti ($p < 0,001$) päritolu toodete vahel. Mida kõrgem kampülobakterite arvukus värske kanaliha pinnal esineb, seda suurem on tõenäosus kampülobakterite ülekandmiseks toidu töötlemise ja tarbimise ahelasse kujutades seeläbi ohtu tarbijate tervisele. EFSA (2011) andmetel on võimalik kampülobakteritest tulenevaid rahvatervise riske vähendada 50% ulatuses, kui kampülobakterite arvukus kana tapapartiide kaela- ja rinnakunahal on <1000 PMÜ g^{-1}, ning koguni 90% ulatuses, kui see arvukus on <500 PMÜ g^{-1}. Hansson jt (2007) leidsid, et isegi kõige paremini planeeritud ja detailne tõrjeprogramm ei garanteeri *Campylobacter* spp. täielikku elimineerimist kanaliha tootmise ahelas, kuna kampülobaktereid leidub laialdaselt kõikjal keskkonnas. Kui rakendatakse rangeid bioohutuse meetmeid, on siiski farmi tasandil võimalik saavutada oluliselt madalamaid *Campylobacter* spp. kontaminatsiooni tasemeid (Rosenquist jt, 2009). Tööstuse tasandil on võimalik ohtusid minimeerida kampülobakterite arvukuse vähendamisega rümpade pinnal, neid kas külm- või kuumtöödeldes (Rosenquist jt, 2003). Selleks, et vähendada *Campylobacter* spp. esinemissagedust kogu kanaliha tootmise ahelas, on oluline ettevõtte tasandil efektiivsete kvaliteediprogrammide (HACCAP printsiipide), heade hügieeni- ja tootmistavade ning bioohutuse meetmete järjekindel rakendamine (Meremäe jt, 2010) ning vajadusel ohje meetmete korrigeerimine (Ma jt, 2014).

Uurimustulemustest selgus, et värske kanaliha *Campylobacter* spp. levimusnäitajates esines 2012. aastal selge hooajaline varieeruvus (joonis 2). Kampülobakterite levimuses esines kõrghooaeg juunist kuni septembrini, kui *Campylobacter* spp. kontaminatsioonimäärad varieerusid vahemikus 16,7–75%. Eestis teostatud varasemad uuringud aastatel 2000–2010 (Roasto jt, 2011; Meremäe jt, 2010) kui teised samalaadsed mujal maailmas teostatud teadusuuringud (Horrocks jt, 2009; Rautelin, Hänninen, 2000) kinnitavad *Campylobacter* spp. levimust eeskätt suvekuudel. Seda seletatakse kampülobakterite sooja- ja niiskuselembusega.



Joonis 1. *Campylobacter* spp. arvukus värskes kanalihas (Mäesaar jt, 2014)
Figure 1. Campylobacter *spp. counts in fresh chicken meat (Mäesaar* et al.*, 2014)*



Joonis 2. *Campylobacter* spp. kontaminatsiooni hooajaline varieeruvus Eesti (EST) ja Leedu (LT) kanalihas (Roasto jt, 2015)
Figure 2. *Seasonality of* Campylobacter *spp. contamination in Estonian (EST) and Lithuanian (LT) origin chicken meat (Roasto* et al.*, 2015)*

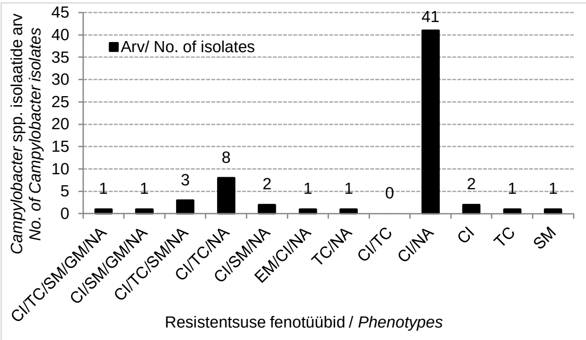
Campylobacter spp. liigiline kuuluvus

Campylobacter spp. liigilise kuuluvuse uuringusse kaasati ühtekokku 98 tüve, milledest 36 olid Eesti, 46 Leedu ja 16 Läti päritolu, mis olid isoleeritud värske kanaliha proovidest aastal 2012. Uuringutulemused näitasid, et 89% nendest kampülobakterite isolaatidest olid määratletud kui *C. jejuni* ja 11% juhtudel oli tegemist *C. coli*'ga. Nii Eesti kui Läti päritolu *Campylobacter* tüved osutusid kõik *C. jejuni*'ks. Leedu päritolu tüvedest kokku 35 (76,1%) osutusid *C. jejuni*'ks ning 11 (23,9%) *C. coli*'ks. Ka meie varasemad teadusuuringud on kinnitanud, et *C. jejuni* on Eesti kanaliha tootmise ahelas kõige enam isoleeritud liik (Roasto jt, 2011; Meremäe jt, 2010), mis on kooskõlas ka teiste riikide samalaadsete uuringutega (Ma jt, 2014; Bunevičienė jt, 2010).

Campylobacter spp. tüvede ravimtundlikkus

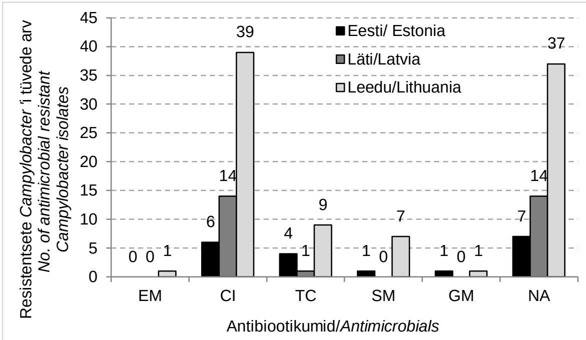
Campylobacter spp. tüvede antibiootikumidele tundlikkuse uuringusse, mis viidi läbi Eesti Teadusagentuuri grandiprojekti (nr 9315) ja Põllumajandusministeeriumi rakendusuuringute projekti (leping nr

T13057VLTH) raames, kaasati liigilise kuuluvuse määramisel valimisse kuulunud 98 kanaliha päritolu tüve. Käesolevas uuringus ei esinenud olulisi erinevusi ($p > 0,05$) *C. jejuni* ja *C. coli* resistentsusfenotüüpide vahel. Tulemustes selgus, et kokku 36 isolaati (36,7%) osutus tundlikuks kõikide testitud antibiootikumide suhtes. Kõige enam esines kampülobakteri isolaatide seas resistentsust tsiprofloksatsiini ja nalidiksiinhappe suhtes ehk ühtekokku 41 isolaati (41,8%) olid fluorokinoloonide suhtes resistentsed (joonis 3). Võrreldes Eestis teostatud varasemate uuringutega aastatel 2005–2007 (Roasto jt, 2007) ja aastatel 2002–2004 (Praakle-Amin jt, 2007), kui *Campylobacter* spp. resistentsus fluorokinoloonidele oli vastavalt 74,5% ja 66%, on 2012.–2014. aasta uurimusperioodil see näitaja siiski mõnevõrra madalam. Uuringus leiti, et kokku kaheksa isolaati (8,2%) olid resistentsed tsiprofloksatsiini/tetratsükliini/nalidiksiinhappe suhtes. Kolm isolaati (3,1%) olid resistentsed samaaegselt tsiprofloksatsiini/tetratsükliini/nalidiksiinhappe/streptomütsiini suhtes. Kaks isolaati (2,1%) olid resistentsed nii kombinatsiooni tsiprofloksatsiini/streptomütsiini/nalidiksiinhappe suhtes kui ka ainult tsiprofloksatsiini suhtes.



Joonis 3. Kanaliha *Campylobacter* spp. isolaatide resistentsusprofiilid (Mäesaar jt, 2015). Antibiootikumid: EM – erütromütsiin, CI – tsiprofloksatsiin; TC – tetratsükliin, SM – streptomütsiin, GM – gentamütsiin, NA – nalidiksiinhape
Figure 3. *Antimicrobial resistance patterns of* Campylobacter *spp. isolates in chicken meat samples (Mäesaar* et al., *2015). Antimicrobial agents: EM – erythromycin, CI – ciprofloxacin, TC – tetracycline, SM – streptomycin, GM – gentamicin, NA – nalidixic acid*

Uuringutulemused näitasid, et Eesti, Läti ja Leedu päritolu *Campylobacter* spp. tüvedel oli antibiootikumidele tundlikkus erinev (joonis 4). Eesti ja Läti päritolu *Campylobacter* spp. tüved osutusid tundlikuks vastavalt erütromütsiini ning erütromütsiini/streptomütsiini/gentamütsiini suhtes. Samas resistentsust ühe või mitme antibiootikumi suhtes esines 7 (19,4%) Eesti, 41 (89,1%) Leedu ja 14 (87,5%) Läti päritolu tüvel. Andmete statistilise töötlemise tulemustest järeldati, et *Campylobacter* spp. resistentsust ühe või enama antibiootikumi suhtes esines Eesti päritolu kanalihalt isoleeritud tüvedel oluliselt ($p < 0,05$) vähem kui Leedu või Läti tüvede hulgas. Võrdluseks, Ma jt (2014) uuring näitas, et kõik 259 (100%) uuritud *Campylobacter* spp. isolaati osutusid resistentseks vähemalt ühe antibiootikumi suhtes, ja nendest tüvedest, mis olid isoleeritud umbsoolest, rümpadelt ja kanalihalt, olid 95,7–100% resistentsed tsiprofloksatsiini suhtes. EFSA (2013) andmetel on murettekitavaks olukorraks *Campylobacter* spp. tüvede kõrge resistentsus tsiprofloksatsiinile. Joonisel 4 selgub, et käesolevas uuringus oli 6 (16,7%) Eesti tüve, 14 (87,5%) Läti ja 39 (84,8%) Leedu tüve resistentsed tsiprofloksatsiini suhtes. Ka nalidiksiinhappe suhtes esines kõrge resistentsus eeskätt Läti (14 tüve, 87,5%) ja Leedu tüvede (37 tüve, 80,4%) seas, millele järgnesid Eesti tüved (7 tüve, 19,4%). Multiresistentsust kolme või enama samasse gruppi mittekuuluva antibiootikumi suhtes esines kokku 5 (5,1%) *Campylobacter* spp. tüvel, neist üks (2,8%) Eesti ja neli (8,7%) Leedu päritolu. Eestis teostatud varasemas uuringus aastatel 2002–2003 multiresistentseid isolaate ei tuvastatud (Praakle-Amin jt, 2007), kuid aastatel 2005–2006 osutusid koguni 36 isolaati (27,5%) multiresistentseks (Roasto jt, 2007). Kirjanduse põhjal võib väita, et antibiootikumi resistentsuse kõrge esinemissagedus kanalihalt isoleeritud kampülobakterite seas viitab antibiootikumide pikaajalisele kasutamisele farmi tasandil (EFSA, 2014; Kovalenko jt, 2014; Roasto jt, 2007). See võib kujutada tõsist ohtu inimeste tervisele, sest farmi tasandilt võivad resistentsed bakterid jõuda ka lihatoodete tarbimise tasandini. Seetõttu on väga oluline rakendada nii kontrolli kui ohje mehhanisme antibiootikumide kasutamise üle farmi tasandil lindude kasvatamisperioodi ajal.



Joonis 4. Ravimresistentsete *Campylobacter*'i tüvede arv pärinedes erinevate riikide kanaliha proovidest (Mäesaar jt, 2015). Antibiootikumid: EM – erütromütsiin, CI – tsiprofloksatsiin, TC – tetratsükliin, SM – streptomütsiin, GM – gentamütsiin, NA – nalidiksiinhape
Figure 4. *Number of antimicrobial resistant* Campylobacter *isolates originating from different countries (Mäesaar* et al., *2015). Antimicrobial agents: EM – Erythromycin, CI – ciprofloxacin, TC – tetracycline, SM – streptomycin, GM – gentamicin, NA – nalidixic acid*

Kokkuvõte ja järeldused

Uurimustulemused näitasid, et Eesti, Läti ja Leedu päritolu linnulihatooted on Eesti jaemüügi tasandil sageli kampülobakteritega saastunud. Võime väita, et võrreldes importtoodetega on Eesti päritolu värskes kanalihas kampülobakterite levimus ja arvukus mädalam. Kuigi kampülobakterite kontaminatsiooni kõrghooaeg Eestis on peamiselt soojadel suvekuudel, võib pidada inimeste kampülobakterenteriiti haigestumise riski kanaliha tarbimisel ebaoluliseest kuni keskmiseni, sõltudes sellest, kas tarbida kodumaist või imporditud toodangut. Selleks, et hoida *Campylobacter* spp. levimus, arvukus ja antibiootikumidele resistentsus võimalikult madal, on oluline ohje meetmete efektiivne rakendamine kogu kanaliha tootmise ahelas alates farmist kuni tarbimiseni.

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The prevalence, counts and antimicrobial susceptibility of thermophilic Campylobacter spp. in fresh chicken meat at Estonian retail level

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Summary

The main aim of the present study is to give an overview about the prevalence, counts and antimicrobial susceptibility of *Campylobacter* spp. in fresh chicken meat at the Estonian retail level in 2012–2014. The detection and enumeration of *Campylobacter* spp. were carried out in accordance with the methods of EVS-EN ISO 10272-1:2006 and ISO/TS 10272-2:2006(E). Conventional multiplex PCR assay was used for identification and differentiation of *Campylobacter* species according to the method described in Wang *et al*. (2002). The VetMIC Camp method (National Veterinary Institute, Uppsala, Sweden) was used in order to test 96 *Campylobacter* isolates against erythromycin, ciprofloxacin, tetracycline, streptomycin, gentamicin and nalidixic acid for MICs. Findings showed that *Campylobacter* spp. are widely present in fresh chicken meat at Estonian retail level. Table 1 shows the prevalence and total counts of *Campylobacter* spp. in chicken meat samples in 2012. *Campylobacter* spp. was isolated in 77 (35%) of 220 chicken meat samples. Altogether, 24 (20.3%) of Estonian origin, 41 (50%) of Lithuanian origin and 12 (60%) of Latvian origin investigated chicken meat samples were positive for *Campylobacter* at retail level. The highest total counts of *Campylobacter* spp., on

average 2600 CFU g^{-1}, were detected in the chicken meat samples of Lithuanian origin followed by on average 1600 CFU g^{-1} and 660 CFU g^{-1} in samples of Latvian and Estonian origin, respectively. Figure 1 shows the results of *Campylobacter* spp. enumeration in fresh chicken meat, which indicated that more than 1000 CFU g^{-1} contained a total of 2 (1.7%) of Estonian, 12 (14.6%) of Lithuanian and 7 (35%) of Latvian origin products. Figure 2 gives an overview about the seasonality of *Campylobacter* spp. contamination on fresh chicken meat of Estonian (EST) and Lithuanian (LT) origin in 2012. High occurrence of *Campylobacter* spp. contamination was observed from June to September. *C. jejuni* was the most frequently (89%) isolated species followed by *C. coli* (11%). A total of 36 isolates (36.7%) of 98 were susceptible to all the tested antimicrobials. The highest proportion of isolates (41 isolates, 41.8%) was resistant to fluoroquinolones. Multiresistance, resistance to three or more unrelated antimicrobials, was detected in 5 (5.1%) isolates. Antimicrobial resistance phenotype of *Campylobacter* spp. isolates in chicken meat samples are shown in Figure 3.

A total of eight (8.2%) isolates were resistant to ciprofloxacin/tetracycline/nalidixic acid. A total of three (3.1%) isolates were resistant ciprofloxacin/tetracycline/streptomycin/nalidixic acid. The combination of ciprofloxacin/streptomycin/nalidixic acid appeared in two (2.1%) isolates. The number of antimicrobial resistant *Campylobacter* isolates originating from different countries has shown in Figure 4, which showed that the antimicrobial resistance was less prevalent among *Campylobacter* isolates of Estonian origin compared to Lithuanian or Latvian origin. Resistance to one or more antimicrobials was detected in 7 (19.4%) of Estonian, 41 (89.1%) of Lithuanian and 14 (87.5%) of Latvian origin *Campylobacter* spp. isolates of chicken meat. In conclusion, compared to fresh chicken meat of Lithuanian and Latvian origin, the prevalence, counts and antimicrobial resistance of *Campylobacter* spp. in chicken meat of Estonian origin were lower. Therefore, we suppose that the risk of occurrence of *Campylobacter* human infection by consuming domestic fresh chicken meat is lower than for imported chicken meat. It is important to improve and strictly follow biosecurity, hygiene and other control measures in the whole chicken production chain for reducing the prevalence and counts of *Campylobacter* spp. in chicken meat.

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ÜLEVAADE METSAOMANIKE KLASSIFITSEERIMISEST IDA-EUROOPA RIIKIDES: METODOLOOGILISI NING METSAPOLIITILISI ASPEKTE

A REVIEW ON FOREST OWNER CLASSIFICATIONS IN EASTERN-EUROPE – METHODOLOGICAL AND POLICY-RELATED ASPECTS

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ABSTRACT. Forest owners are an important group of people as they own and use a significant amount of our land resources. Their choices, decisions and behaviour are closely related to the benefits that forests provide to everyone. It is for this that information is needed about forest owners and their behaviour. Private forest ownership in Central and Eastern European countries is relatively new and there is not much knowledge about the new forest owners. Therefore, several owners' classification studies have been made in different countries. The aim of this paper is to give an overview about some forest owners' classification cases in this region. Observed typologies and the methodological aspects are compared between the country cases and their policy importance is discussed. In almost all such studies, quite universal forest owner groups are found – the economically and ecologically oriented, the multiple users or producers and indifferent or passive owners. Depending on the data and specific clustering methods some variations of course exist. The similarity and the broad description of groups rises a question if such larger-scale classifications are in fact depleted. Also, there are several methodological downsides in the used clustering processes. Nevertheless, such classifications are useful for designing large-scale and long-term objectives for management of forest resources. This is due to the high level of generalization of these owner types. However, using such classifications for designing more specific tools for particular groups, might not be appropriate. Instead, qualitative research in describing particular owner groups might give new and more in-depth information about the characteristics of private forest owners. Also, these results might help more in developing forest and environmental policy tools.

Sissejuhatus

Metsandussektor on paljudes Ida-Euroopa riikides viimase kahe aastakümne jooksul palju muutunud. Üheks universaalseks asjaoluks nende muutuste juures on see, et märkimisväärne hulk metsaressursist on liikunud eraomandisse. See tähendab näiteks seda, et kolmes Balti riigis on kokku ligikaudu pool miljonit eraomanikku (Forinfo, 2011; Mizaraite jt, 2010; Vilkriste, 2006), mis moodustab umbes 7–8% nende riikide elanikkonnast, ning nende inimeste metsaomand moodustab umbes 45% riikide kogu metsavarust. Kindlasti tuleb siinjuures arvestada asjaolu, et tegemist on dünaamilise olukorraga – paljudes riikides on pooleli veel maade tagastamine või erastamine (Sarvašova jt, 2015), toimuvad maatehingud avatud turul, muutub üldine sotsiaalmajanduslik olukord.

Lisaks metsaomandile on suuri muutusi läbi teinud ka metsapoliitilised protsessid ning seda mitte ainult omandi muutustest tingitult. Pigem on küsimus laiemas ühiskondlikus arengus ning metsandussektori eripäras pakkuda väga suures ulatuses erinevaid tooteid ja teenuseid. Nende eri funktsioonide tagamiseks rakendatakse keskkonna- ja metsapoliitilisi vahendeid. Suur osa neist vahenditest on suunatud just erametsaomanikele. Edukas poliitikate rakendamine eeldab teadmisi sihtrühmast ehk eraomanikest – nende omandist, soovidest ja vajadustest. Paraku on Eesti puhul neid teadmisi veel endiselt vähe, nagu tõdetakse ka Eesti metsanduse arengukavas aastani 2020 (Keskkonnaministeerium, 2010, lk 26). Pregernig (2001) aga näiteks rõhutab, et metsapoliitiliste instrumentide loomine ja rakendamine peakski toimuma just sihtrühmade põhiselt.

Üks tavapärane ja üsna levinud viis metsaomanike kui sihtrühma uurimiseks on nende rühmitamine. Metsaomanike tüüpide loomine on tõenäoliselt üks levinumaid metsapoliitilisi uurimisvaldkondi üldse, sest see võimaldab kirjeldada ja lihtsustada metsaomanike mitmekesisust (Weber, 2012). Klassifitseerimiseks kasutatakse üldjoontes kahte erinevat lähenemist (Smith, 2002). Nii tüpoloogiate kui ka taksonoomiate kujundamise eesmärk on lihtsustada mingit keerukat süsteemi. Mõlemal juhul on aga tegemist klassifitseerimise erijuhtudega, kuigi nende väljund on üldjoontes sama – mingite subjektide liigitamine või grupeerimine sarnasuste alusel (Bailey, 1994). Nende omavaheline erinevus seisneb selles, et taksonoomiad lähtuvad ennekõike mõõdetavatest empiirilistest näitajatest, ent tüpoloogiad on mitmemõõtmelised ja kontseptuaalsed (Bailey, 1994). Tõsi, tihtipeale kasutatakse neid sõnu sünonüümidena. Siiski on vahe märgatav ka asjaolus, et taksonoomiatest räägitakse peamiselt loodusteadustes ning tüpoloogiatest poliitika- ja sotsiaalteadustes. Just viimastest on metsapoliitika võtnud üle teoreetilisi lähenemisi ja praktikaid, jäädes samal ajal siiski tugevalt oma uurimisobjekti keskseks (De Jong jt, 2012).

Metsaomanike tüüpide või rühmade uuringuid on tehtud palju just pikema eraomandi ajalooga riikides: Ameerika Ühendriigid (nt Finley, Kittredge, 2006; Finley jt, 2006; Majumdar jt, 2008), Austria (nt Hogl jt, 2005), Soome (nt Karppinen, 1998), Rootsi (nt Ingemarson jt, 2006) jmt. Selline uurimissuund on aga uudne just riikides, kus maaomandiga seotud muutused on veel võrdlemisi uued. Seetõttu on selle ülevaate eesmärgiks võrrelda eri Ida-Euroopa riikide metsaomanike rühmitamise uuringute tulemusi ning nende metodoloogilisi aspekte. Samuti arutletakse nii leitud rühmade kui ka metodoloogiliste nüansside olulisuse üle metsapoliitilises kontekstis.

Materjal ja metoodika ning arutelu

Lähtudes püstitatud eesmärgist, toetub see analüüs ennekõike olemasolevale teaduskirjandusele. Vaatluse all olevad uurimused on rahvusvahelises teaduskirjanduses praegu ainukesed autorile teada olevad näited Ida-Euroopa riikide metsaomanike tüpoloogiate kohta (Eesti näide baseerub Teet Sepa magistritööl). Nende leidmiseks kasutati andmebaaside, nagu *Scopus*, *Thompson Web of Science* ja *ScienceDirect* otsinguid. Otsingute käigus leiti järgmiste riikide metsaomanike rühmitamise näiteid (lisaks Eesti näitele Sepp, 2008): Leedu (Stanislovaitis jt, 2015; Mizaraite, Mizaras, 2005), Ungari[1] (Elands jt, 2004; Wiersum jt, 2005), Serbia (Malovrh jt, 2015) ja Sloveenia (Malovrh jt, 2015). Uurimuste võrdlemisel kasutati kvalitatiivset juhtumipõhist sisuanalüüsi, mille abil võrreldi kõikide uuritavate juhtumite käigus leitud metsaomanike rühmade kirjeldusi. Selgitati, kuidas on analüüside läbiviijad loodud rühmi interpreteerinud ning millised on juhtumitevahelised sarnasused ja erisused. Lähtudes sellest, teostati ka täiendav, lihtsustatud juhtumiteülene grupeerimine. Samuti võrreldi uurimuse metoodilisi lähenemisi ning hinnati nende metsapoliitilist olulisust.

Rühmitamise lähteandmed ja meetodid

Vaadeldud uurimuste seas on rõhk valdavalt olnud empiiriliste tulemuste analüüsimisel (tabel 1). Viiel juhul kuuest on andmete kogumiseks kasutatud ankeetküsimustikke, mille peamine fookus on olnud välja selgitada, kuidas hindavad metsaomanikud oma eesmärke. Vaid üks vaatluse all olnud uurimustest kasutas kvalitatiivset lähenemist (intervjuud ja sisuanalüüsi), samal ajal kui selle eesmärk oli vaadeldud kvantitatiivsete uurimuste omaga sarnane. Üldjoontes on ankeetküsimustike kaudu andmete kogumiseks levinum viis kasutada eri seisukohtade väljaselgitamiseks 5-punktilist Likerti skaalat (nt Finley, Kittredge, 2006; Jennings, van Putten, 2006; Karppinen, 1998; Urquhart, Courtney, 2011 jpt).

Vaatluse all olevates uuringutes küsis näiteks Sepp (2008) omanikelt, millest nad metsaraiete tegemisel lähtuvad. Üheks vastusevariandiks oli "isiklikust majanduslikust olukorrast (suurem summa raha)", mida metsaomanikud on pidanud hindama vastavalt kui "kõige olulisem", "väga oluline", „oluline", "vähem oluline" või "ei oma tähtsust". Sarnaselt on Malovrh jt (2015) küsinud eri eesmärkide, nagu näiteks puidu tootmise, mittepuiduliste saaduste tootmise, puhkuse, jahinduse, tulevikku investeerimise, elurikkuse kaitse, metsa kaitse kohta, aga skaala keskmine väärtus on "neutraalne", mitte "oluline", nagu kasutas Sepp (2008). Teatud juhtudel on kasutatud lähteandmetena ka mitmeid eri küsimuste vastuseid koos. Näiteks Malovrh jt (2015), Elands jt (2004) ning Wiersum jt (2005) kasutavad nii diskreetseid kui ka pidevaid muutujaid koos (näiteks metsaomandi suurus). Muutujate tüübist olenevalt on kasutatud klasteranalüüsi eri meetodeid, et olemasolevast andmestikust rühmad luua. Suuremate andmestike puhul on mõningail juhtudel enne kasutatud lihtsustamismeetodeid (faktoranalüüs või eelklastrite loomine). Samuti on näiteks Sepp (2008) kasutanud CCC-kriteeriumi (*cubic cluster criterium*), mille tulemusena saadakse teada konkreetsete vaatluste jaoks optimaalne klastrite arv.

[1] Ungari juhtum on osa suuremast Euroopa projektist *"Multifunctional forestry as a means to rural development"* (Multifor.RD), mistõttu esineb selle juhtumi kirjeldamisel teatavaid iseärasusi. Näiteks on autorid rühmitanud omanikke erinevate põhimõtete alusel erinevatesse rühmadesse, mistõttu esineb ka tulemuste kajastamisel erisusi.

Tabel 1. Vaadeldud uurimuste mõningate metodoloogiliste aspektide võrdlus
***Table 1.** Comparison of some methodological aspects of the reviewed studies*

Riik *Country*	Allikas *Source*	Valimi suurus *Sample size*	Kvantitatiivne *Quantitative*	Kvalitatiivne *Qualitative*	Eesmärk *Aim of the study*	Valimi valiku põhimõtted *Sampling principles*	Metoodika *Methods*
Eesti *Estonia*	Sepp, 2008	459	X		Erametsaomanike rühmitamine nende käitumise ja hoiakute alusel *Owners classification based on their behaviour and attitudes*	Toetusmeetmete andmebaas ja metsaregistri väljavõte *Sample taken from forestry support database and Forest Register*	Klasteranalüüs (SAS). Vastusevariantidega küsimustiku analüüs. *Cluster Analysis (SAS) of multiple choice questionnaire*
Leedu *Lithuania*	Stanislovaitis jt, 2015	18		X	Leedu erametsaomanike üksikasjalik kontekstuaalne kujutamine *Provide detailed contextualized portrayals of private forest owners in Lithuania*	Žemaitija ja Suvalkija piirkonnad *Regional areas of Žemaitija and Suvalkija*	Intervjuu sisuanalüüs. Eesmärkidel ja käitumisel baseeruvate rühmade loomine ning ekspertarvamuste rakendamine tüüpide esinemise selgitamiseks kahel valitud alal *Content analysis of interviews. Grouping owners based on their objectives and behaviour. Generalizing the identified groups to two specific areas using expert opinions*
	Mizaraite, Mizaras, 2005	415	X		Selgitada metsaomanike eesmärke ning metsade majandamisega seotud probleeme ning grupeerida omanikke lähtuvalt nende eesmärkidest *Explain forest owners goals, their management related problems and group them based on their objectives*	Üleriigilise registri geograafiliselt esinduslik väljavõtt *Random selection from the database of the public company 'Registrų Centras'*	Klasteranalüüs (STATISTICA). Vastusevariantidega küsimustiku analüüs. Aluseks 5-punktiline Likert skaala metsaomanike eesmärkidest *Cluster Analysis (STATISTICA) of multiple choice questionnaire. Clustering based on 5-point Likert scale answers to their objectives*
Ungari *Hungary*	Wiersum jt, 2005; Elands jt, 2004	794	X		Selgitada mis muutujad iseloomustavad väikemetsaomanikke, mis on metsaomanike eesmärgid ning kuidas nad tajuvad maalisust *Explain the characteristics of small-scale forest owners, their objectives and how they perceive forests within rural development*	Kahe piirkonna (Szentgál ja Kerekegyháza) baasil võetud valim *Sample based on two distinct areas (Szentgál ja Kerekegyháza)*	Faktoranalüüsi (varimaks pööramisega) kasutati andmestiku lihtsustamiseks ja väiksemaks muutmiseks. Rühmitamiseks kasutati esmalt hierarhilist klasterdamist mille tulemustele rakendati k-keskmist klasteranalüüsi *Factor analysis (with VARIMAX rotation) was used to simplify the dataset. For grouping both hierarchical and K-means clustering was used*
Serbia *Serbia*	Malovrh jt, 2015	248	X		Selgitada metsaomanike tüüpe lähtuvalt erinevatest kriteeriumitest (eesmärgid, koostöövalmidus jm.) ning sellest lähtuvalt anda soovitusi poliitika-instrumentide kasutamise kohta *To idenfity and describe private forest owner types based on various criteria ((1) forest management objectives, (2) participation in private forest owner organizations etc.) and give suggestions which policy instruments should be used*	Lähtutakse omandi suuruse ja geograafilisest esinduslikkusest. Eri riikide puhul kasutatud aga eri allikaid riikide iseärasusest tulenevalt *Ownership size and geographical representativeness as base for selection however, different sources are used in both countries*	Kaheastmeline klasteranalüüs (SPSS 20), et optimeerida klastrite moodustamist (eelklastrite moodustamine). Hilisematele eelklastritele rakendati hierarhilist klasteranalüüsi. Muutujate seas on nii pidevaid kui ka diskreetseid muutujaid *Two-step cluster analysis (SPSS 20) was used to optimize the formation of clusters. Later hierarchical clustering was applied (both continuous and categorical variables were used)*
Sloveenia *Slovenia*	Malovrh jt 2015	322	X				

Rühmade sarnasused ja erinevused

Vaadeldud uurimuste võrdlemisel on kõige esimeseks ja selgemaks ühisosaks see, et kõikides esineb selline grupp metsaomanikke, kelle peamiseks eesmärgiks on aktiivne majandustegevus (tabel 2). Mizaraite ja Mizaras (2005) nimetavad neid Leedu puhul "ärimeesteks" ning nende osakaal on koguni 29%. Stanislovaitis jt (2015) leidsid neid olevat 18%. Jättes kõrvale asjaolu, et ühel juhul on tegemist kvantitatiivse ning teisel juhul kvalitatiivse analüüsiga, on üheks suureks osakaalu erinevuse põhjuseks kindlasti asjaolu, et Mizaraite ja Mizaras (2005) kasutasid üle-Leedulist esinduslikku valimit, samal ajal kui Stanislovaitis jt (2015) keskendusid kahele konkreetsele Leedu piirkonnale. Serbia ja Sloveenia puhul on rühm nimetatud "aktiivseteks metsaomanikeks" ning nende osakaalud on vastavalt 33% ja 26% (Malovrh jt, 2015). Võrreldes teiste rühmadega, on sellised metsaomanikud aktiivsemad majandajad, nad peavad oluliseks puidukasutust kui sissetulekuallikat. Üldjoontes on neil ka rohkem metsamaad kui metsaomanikel, kes kuuluvad teistesse gruppidesse. Tehingud (ennekõike ost) metsamaaga on sellistel metsaomanikel pigem tõenäolisemad, kuivõrd metsa vaadeldakse kui investeeringuobjekti.

Oma omandi karakteristikutelt ei erine eelmisest rühmast palju ka metsaomanike grupp, kel on metsaga mitu eesmärki. Sepp (2008) on nad nimetanud "mitmekülgseteks tootjateks" ning sarnased rühmad eristuvad ka Leedus (Mizaraite, Mizaras, 2005) ning Serbias ja Sloveenias (Malovhr jt, 2015). Serbia puhul on suur osakaal (67%) tingitud ennekõike asjaolust, et klastreid oli vaid kaks. Tegelikult langeb selle rühma alla kirjelduste poolest vähemalt osaliselt ka Leedu (Stanislovaitis jt, 2015) rühm "kodune metsamees" (56%), Ungari-1 (Wiersum jt, 2005; Elands jt, 2004) "talumetsaomanikud" (83%) ja Ungari-2 (Wiersum jt, 2005; Elands jt, 2004) "hobimetsaomanikud" (54%). Majandamine toimub harvem, on väiksema intensiivsusega. Osa puitu kasutakse ära koduses majapidamises. Maapiirkondades elavad siia rühma kuuluvad metsaomanikud on tihtipeale tegevad ka põllumajanduslikus tootmises. Mõneti sarnaneb selle rühmaga ka Mizaraite ja Mizarase (2005) rühm "tarbijad" (23%).

Ennekõike Leedu näidete puhul eristub veel looduse-armastajate rühm (Stanislovaitis jt, 2015; Mizaraite, Mizaras, 2005). Neile metsaomanikele kuulub pigem vähem metsa, nad on majandamisel väheaktiivsed või puudub aktiivsus üldse. Majandamine piirdub üldjoontes tegevustega, mis parandavad metsa üldist seisukorda. Sepp (2008) leidis sarnase rühma, mille nimetas "kõrvalseisjateks". Kuigi ta leidis, et keskkonnakaitselisi ja sotsiaalseid aspekte need metsaomanikud kõrge väärtusega ei hinnanud, on klastrisse kuuluvate metsaomanike tegevuse kirjeldusest näha selgeid paralleele Leedu näidetega. Ühtlasi esineb selles rühmas huvi metsa rekreatiivsete väärtuste vastu. Kuigi Malovrh jt (2015) on Sloveenia näitel klastri "passiivseteks omanikeks" nimetanud, on ka siin paralleele eelmainitud näidetega: metsade majanduslikud aspektid on pigem väheolulised ja samal ajal on puhkemajanduslikud väärtused metsaomanikele olulisemad.

Tabel 2. Vaadeldud uurimustest üldistatud metsaomanike grupid
Table 2. *Generalized forest owner groups in the observed studies*

Üldistatud nimetus *Generalized name*		Aktiivsed metsade majandajad *Active forest managers*	Mitme eesmärgiga metsaomanikud *Multi-objective forest owners*	Loodushoiu ja puhkuse eesmärkidega omanikud *Conservation and recreation motivated owners*	Passiivsed/mittehuvitatud omanikud *Passive/not interested owners*
Riik *Country*	Uurimus *Source*	Rühma nimetus *Group name (%)*	Rühma nimetus *Group name (%)*	Rühma nimetus *Group name (%)*	Rühma nimetus *Group name (%)*
Eesti *Estonia*	Sepp, 2008	Puidukasutusele orienteeritud tootjad *Timber-oriented producers* (23)	Mitmekülgsed tootjad *Versatile producers* (10)	Kõrvalseisjad *Bystander* (27)	Ükskõiksed metsaomanikud *Indifferent forest owners* (32); Väheaktiivsed metsaomanikud *Less active forest owners* (8)
Leedu *Lithuania*	Stanislovaitis jt, 2015	Ärimees *Forest businessman* (18)	Kodune metsamees *Household forester* (56)	Passiivne metsaarmastaja *Passive forest lover* (7)	*Ad-Hoc* omanik *Ad hoc owners* (19)
	Mizaraite, Mizaras, 2005	Ärimehed *Businessmen* (29)	Mitme-eesmärgilised omanikud *Multi-objective owners* (30); Tarbijad/*Consumers* (23)	Loodussõbrad *Ecologists* (18)	
Ungari-1 *Hungary-1*	Wiersum jt, 2005; Elands jt, 2004	Metsnikud *Foresters* (17)	Talumetsaomanikud *Farm-foresters* (83)		
Ungari-2 *Hungary-2*	Wiersum jt, 2005; Elands jt, 2004	Täistööajaga omanikud *Full time owners* (8)	Hobimetsaomanikud *Hobby-owners* (54)		Pensionil metsaomanikud *Retired owners* (37); Osalise tööajaga omanikud *Part-time owners* (1)
Serbia *Serbia*	Malovrh jt 2015	Aktiivsed omanikud *Active owners* (33)	Mitme-eesmärgilised omanikud *Multiobjective owners* (67)		
Sloveenia *Slovenia*	Malovrh jt 2015	Aktiivsed omanikud *Active owners* (26)	Mitme-eesmärgilised omanikud *Multiobjective owners* (19)	Passiivsed omanikud *Passive owners* (33)	Mittehuvitatud omanikud *Uninterested owners* (22)

Viimati mainitud passiivsete omanike rühmi leidub aga veel mujalgi. Nii Sepp (2008) kui ka Stanislovaitis jt (2015) on selliseid metsaomanike rühmi leidnud, nimetades neid vastavalt "ükskõiksed metsaomanikud" (32%) ja "*ad hoc*-omanikud" (19%). Selles rühmas olevad metsaomanikud ei tegele oma metsa majandamisega või teevad seda oma metsa seisukorra parandamiseks. Sloveenia näitel nimetati rühm "mittehuvitatud metsaomanikeks" (22%), kes omavad väga väikeseid metsaosi, elades ise samal ajal eemal linnades (Malovrh jt, 2015). Sepp (2008) leidis Eesti näitel aga pigem vastupidist.

Klassifitseerimise metodoloogilised aspektid

Nagu eespool kirjutatud, on igasuguse rühmitamise eesmärgiks lihtsustada keerukat süsteemi, rühmitades suurt populatsiooni sarnaste tunnuste alusel. Metsaomanike puhul on üldjoontes nendeks tunnusteks kas 1) nende väärtused ja eesmärgid, 2) nende käitumine või 3) metsaomandi omadused. Peamiselt on klassifitseerimise sisendiks nii pidevaid kui ka diskreetseid muutujaid ning neid võib olla väga palju. Klasteranalüüsi, mida valdavalt kasutatakse, üks tugevus seisnebki suuremast kogutud andmestikust üsna hea ja kiire ülevaate saamises. Selline klassifitseerimine on ka kasulik, kui tekkivaid rühmi on optimaalne arv. See tähendab, et olemasolevad rühmad kirjeldaksid ära võimalikult suure osa kogu algse valimi tunnuste variatsioonist ja oleksid samal ajal ka üksteisest erinevad. Väga suure arvu rühmade juures aga tekib liialt palju "halli ala" ehk rühmitamise otstarbekus tuleks üle vaadata. Samas väga väikese arvu klastrite juures on üldistuse tase liiga suur ning seetõttu saadud tulemus väheinformatiivne. Selle ülevaate juures osutusid näiteks Serbia (Malovrh jt, 2015) ja Ungari-1 (Wiersum jt, 2005; Elands jt, 2004) näited väga väheinformatiivseks.

Eelmainitud suure klastrite arvu juures tekkiv n-ö hall ala on seotud ühe klasteranalüüsi peamise nõrkusega ehk valdav osa rühmitamist toimub mudelitega, mis arvutavad muutujate alusel rühmade keskmised ning paigutavad üksikud vaatlused klastritesse just nende kauguse järgi moodustatud klastrite keskmistest. Seega võivad arvutatud keskmistest kaugemal asuvad vaatlused eri rühmade piirilähedasse tsooni jääda ning algandmetest või konkreetsest meetodist tulenevalt võib saada nii arvult kui ka sisult väga erinevaid klastreid. Veelgi enam, tuleb arvestada, et ühe klastri sees olevad kaks vaatlust võivad asuda väärtuste poolest üksteisest kaugemal kui eri klastrites asuvad kaks eri vaatlust. Čabaravdić jt (2011) näitasid Bosnia-Hertsogoviina metsaomanikke rühmitades, kui erinevalt võivad grupid tekkida. Kasutades üksnes omandi suuruse näitajat, jaotati metsaomanikud kolme rühma; kaheastmelise klasterdamisega, kus kasutati nii pidevaid kui ka diskreetseid muutujaid, saadi rühmade arvuks samuti kolm, ent rühmade iseloomustused olid eri lahendusi kasutades erinevad. Veelgi enam muutusi tuli tulemustesse, kui aluseks võeti ka omandi asumise piirkond ning rakendati hierarhilist klasterdamist – siis saadi tulemuseks viis eri rühma omanikke. Čabaravdić jt (2011) rõhutavad, et uurimuse eesmärki formuleerides tuleb meetodite kasutamine juba aegsasti läbi mõtelda, sest lisaks klasterdamisele on olemas ka muid rühmitamise võimalusi. Näiteks Wiersum jt (2005) ning Elands jt (2004) kasutasid andmete esialgseks lihtsustamiseks faktoranalüüsi, Põllumäe jt (2014) kasutas Eesti metsaomanike motiivide uurimisel peakomponentanalüüsi. Viimane eristub klasteranalüüsist selle poolest, et algsete tunnuste alusel moodustatakse lineaarkombinatsioonid ehk uued muutujad (komponendid), mis arvutatakse igale vaatlusele eraldi. Tekkivad komponendid kirjeldavad omakorda (sealjuures esimene kõige rohkem) algsete tunnuste varieeruvust.

Lisaks sellele on valdav osa sellelaadseid metsaomanike uuringuid kvantitatiivsed ning rühmitamise aluseks on tihtipeale ankeetküsimustikud, kus metsaomanikud peavad vastama etteantud seletustele. Vaadeldud näidete puhul olid aluseks metsaomanike eesmärgid – Boon jt (2004) tõdevad oma ülevaates samuti, et peamiselt lähtuvad sellised tüpoloogiad metsaomanike eesmärkidest. Selliselt saadud andmestike puhul on aga oluline silmas pidada, et näiteks metsaomandi eesmärkide nimistusse kirjutatud variante, nagu sissetulek, elurikkus, turism, investeering vms, on juba küsimustiku looja mõistnud üht väga konkreetset moodi. Suure hulga metsaomanike seas aga ei ole universaalset teadmist, mis on elurikkus või milline on oluline sissetulek ja milline mitte. Bengston jt (2011) on metsaomanike kinniseid ja avatud vastuseid võrreldes leidnud, et just viimaste kvalitatiivsel analüüsimisel on ilmekamalt välja tulnud metsaomanike motiivide või eesmärkide mitmekesisus, võrreldes fikseeritud vastuste empiirilise analüüsimisega. Seda metodoloogilist tugevust rõhutavad ka Stansilovaitis jt (2015).

Kas uus info või taasavastatud vana?

Võrreldes eri Lääne-Euroopa riikide metsaomanike rühmitamisi, on Boon jt (2004) kokkuvõttes tõdenud, et valdavalt on omanikud jagunemas viide peamisesse rühma: 1) majandaja ("*economist*"), 2) mitme eesmärgiga omanik ("*multiobjective*"), 3) väikeettevõtja ("*self-employed*"), 4) puhkaja ("*recreationist*") ning 5) passiivne metsaomanik ("*passive/resigning owner*"). Selle artikli raames vaadeldud Ida-Euroopa riikide metsaomanike rühmad (tabel 2) ei erine märkimisväärselt Booni jt (2004) leitust. Võib-olla on üheks suurimaks erisuseks nende leitud väikeettevõtjate rühm, mille esinemist üheski Ida-Euroopa näites nii selgelt välja ei joonistunud. Tõsi, ka Booni jt (2004) ülevaates selgus, et seda rühma esines võrdlemisi vähestes uurimustes.

Uurides 31 eri metsaomanike tüpoloogiate uuringut Euroopast ja Ameerika Ühendriikidest, on Blanco jt (2015) leidnud, et on olemas väike hulk metsaomanike tüüpe, mida eri riikide uurimustest järjekindlalt leida võib: kasumile orienteeritud omanikud, mitme eesmärgiga omanikud, vaba aja / puhkamise eesmärgiga omanikud, looduskaitsjad ja passiivsed omanikud. Vaadeldud Ida-Euroopa uurimuste tulemused on eelmistega üsna sarnased (tabel 2). Selliste tüpoloogiate kasutamine on ehk võimalik laiemate (riigid, riikideülesed regioonid) piirkondade maakasutuspoliitikate kujundamisel. Lokaalsete keskkonna- või majanduspoliitiliste tingimuste tõttu võib samade eesmärkide ja suhtumisega metsaomanike tegelik käitumine olla väga erinev (Blanco jt, 2015). Seetõttu on oluline, kas ja kuidas metsaomanike tüpoloogiaid metsapoliitika kujundamisel, aga ennekõike lokaalsel juurutamisel, arvestatakse.

Metsapoliitilised seosed ja olulisus

Ühiskonnale on oluline, et metsa eri funktsioonid oleksid täidetud. Selle kindlustamiseks kasutab riik mitmesuguseid poliitikaid, et sihtgruppide käitumist suunata või mõjutada. Metsaomanikud on kindlasti ühed kõige olulisemad subjektid, mida eri poliitikainstrumentidega mõjutada üritatakse. Instrumente on samuti väga erinevaid. Näiteks Böcher (2012) jaotab nad neljaks olenevalt riigi mõju ulatusest: regulatoorsed, majanduslikud, koostöölised ja informatiivsed. Serbruyns ja Luyssaert (2006) kasutavad instrumentide kolmeks jaotamist: majanduslikud (nn *porgandid ehk "carrots"*), regulatoorsed (nn *pulgad ehk "sticks"*) ning informatiivsed (nn *jutlused ehk "sermons"*). Miks just omanike klassifitseerimine selles kontekstis oluline on? Kuivõrd tegemist on väga heterogeense sihtrühmaga, võimaldaks selline populatsiooni lihtsustamine paremini analüüsida metsapoliitiliste instrumentide valikupõhimõtteid ning nende tulemuslikkust. Janota ja Broussard (2008) kombineerisidki oma analüüsis metsaomanike motivatsioone ja muid näitajaid, et modelleerida maaomanike instrumentide eelistusi. Oma järeldustes tõdevad nad, et erametsanduse poliitikainstrumendid peaksid enam rõhku panema metsaomanike motivatsioonidele, looduskaitselisse vastutusse suhtumisele ja tegutsemise mõjudest teadlikkuse hoiakutele.

Ka siinkohal vaadeldud uurimustes jõuti paljuski sarnastele järeldustele. Nii Wiersum jt (2005), Stanislovaitis jt (2015), Mizaraite ja Mizaras (2005) kui ka Malovrh jt (2015) tõdevad, et erametsanduse poliitikatega suunamisel peaks arvestama selle mitmekesisust, sest eri instrumendid mõjuvad eri tüüpi metsaomanikele erinevalt. Näiteks toovad Malovrh jt (2015) välja, et aktiivsemad metsaomanikud vajaksid rohkem võimalusi koostööks (ühised investeeringud ja lepingud), et oma metsi majandada, ning passiivseid metsaomanikke peaks samal ajal suunama rohkem regulatoorselt ja informatiivselt. Stanislovaitis jt (2015) järeldavad ennekõike, et riigi poliitikate rakendamine on ajalooliselt jäik ega vasta enam reaalsusele ning metsapoliitika juurutamine peaks olema paindlikum.

Kokkuvõte ja järeldused

Vaatluse all olnud riikide metsaomanike klassifitseerimise uurimustes välja toodud rühmad olid paljuski sarnased. Suurema klasside arvu puhul (4–5) eristusid selgelt sarnased rühmad: majanduslikele eesmärkidele keskenduvad metsaomanikud, mitme eesmärgiga metsaomanikud, looduskaitselistele või puhke-eesmärkidele keskenduvad omanikud ning passiivsed omanikud. Metsaomanike empiirilisel klassifitseerimisel on oluline, et loodavate klasside arv oleks optimaalne, sest väikese klasside arvu puhul tekivad väheinformatiivsed klastrid ning suure klastrite arvu korral tekivad vähe eristuvad metsaomanike rühmad. Vaadeldud Ida-Euroopa näidete raames valminud klassid ei erinenud suures plaanis paljudest teistest klassifikatsioonidest, mis on tehtud riikides, kus erametsaomand on olnud juba pikemat aega. Suurem osa spetsiifilistest erinevustest on tingitud pigem metodoloogilistest nüanssidest kui tegelikust metsaomanike erinevusest. Seda juba seetõttu, et sellise klassifitseerimise tulemusena saame metsaomanike mitmekesisusest väga üldistatud pildi, ning kuigi see võimaldab eraomanikest teatud pildi loomist, on selle üldistuse tase ka üsna limiteerivaks faktoriks. Eri presenteeritud tulemused viitavad pigem sellele, et selline klassikaline metsaomanike tüpoloogiate loomine on vähemalt parasvöötme piirkonnas ennast ammendanud. Eri omadustega metsaomanike kvalitatiivne kirjeldamine võib anda rohkem infot ning võib ka poliitikate kujundamisel, aga ennekõike juurutamisel, kasulikumaks osutuda.

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A review on forest owner classifications in Eastern-Europe – methodological and policy-related aspects

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Summary

Forest owners are an important group of people as they own and use a significant amount of our land resources. Their choices, decisions and behaviour are closely related to the benefits that forests provide to everyone. It is for this that information is needed about forest owners and their behaviour. Private forest ownership in Central and Eastern European countries is relatively new and there is not much knowledge about the new forest owners. Therefore, several owners' classification studies have been made in different countries. The aim of this paper is to give an overview

about some forest owners' classification cases in this region. Observed typologies and the methodological aspects are compared between the country cases and their policy importance is discussed. In almost all such studies, quite universal forest owner groups are found – the economically and ecologically oriented, the multiple users or producers and indifferent or passive owners. Depending on the data and specific clustering methods some variations of course exist. The similarity and the broad description of groups rises a question if such larger-scale classifications are in fact depleted. Also, there are several methodological downsides in the used clustering processes. Nevertheless, such classifications are useful for designing large-scale and long-term objectives for management of forest resources. This is due to the high level of generalization of these owner types. However, using such classifications for designing more specific tools for particular groups, might not be appropriate. Instead, qualitative research in describing particular owner groups might give new and more in-depth information about the characteristics of private forest owners. Also, these results might help more in developing forest and environmental policy tools.

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COMPETITIVENESS OF THE ESTONIAN DAIRY SECTOR, 1994–2014

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ABSTRACT. Historically, the dairy sector has been one of the most important and competitive branches of the Estonian agriculture and food industry. Since the beginning of the transitional period 25 years ago, Estonian society and its economy have gone through significant institutional, political and societal changes, which have also affected the dairy sector. This paper provides a review of the competitiveness of the Estonian dairy sector. The competitiveness of dairy farms, the dairy processing industry and dairy exports are discussed from several perspectives applied in the studies of competitiveness. Also, the context of the transition to a market economy and institutional, policy and market changes are considered. In the past 20 years, the Estonian dairy sector has maintained its competitiveness in export markets. However, there are several aspects that need to be addressed in order to maintain competitiveness in the long term. Estonian dairy farms need to increase their total factor productivity. The negative trends in the declining lifespan of dairy cows and declining content of milk components should be stopped. The Estonian dairy processing industry needs to increase labour productivity and value per kg of processed milk. To avoid the negative effects of specialisation on certain products and markets, the portfolio of export markets and products should be expanded. The EU dairy market is going through deregulation, and farm payments in Estonia fell in 2014. This is not the first time in 20 years that agricultural policy has not been overly protective of the dairy sector. Therefore, the future competitiveness of the Estonian dairy sector depends mainly on its adaptive capacity in the light of changing markets, policies and institutions.

Introduction

Dairy has been one of the most important export orientated sectors in the Estonian agriculture and food industry. In 1925, food and drinks comprised 28.7% of the value of total exports, and butter alone comprised 22.1% of the value of total exports. In 1924/1925, animal products comprised 53.3% of the value of Estonian agricultural output (Pihlamägi, 2004). In 2014, the share of animal products in total agricultural output was 46.5%, and milk comprised 27.8% of the value of Estonian agricultural output. In 2013, the manufacturing of dairy products comprised 2.3% of value added in manufacturing, and 0.5% of total value added. In 2014, milk and dairy products comprised 1.6% of the value of total exports (Statistics Estonia, 2015). If one considers the value of other products of dairy farms (*e.g.* cattle, fodder, cereals, and oilseeds)[1], and the value created in other segments (both up- and downstream) of the milk value chain (*e.g.* input providers, logistics, dairies, retailers, education, research and development, *etc*.), the significance of dairy and associated activities in the Estonian economy is larger than the abovementioned figures suggest. As dairy is an export-orientated branch, with 135.9 million euros' worth of net dairy exports in 2014, it is crucial that the dairy sector maintains and strengthens its competitiveness on external markets in order to sustain the leading role in Estonian agri-food value chains.

[1] According to the authors' calculations based on the standard results of the Estonian FADN survey in 2014 (Rural Economy Research Centre, 2015b), specialised dairy farms comprised 36.9% of total labour use, 46.1% of total output, 43.4% of intermediate consumption, 35.3% of total assets and 44.7% of total liabilities of all farms represented by Estonian FADN sample (FADN Public Database, 2015).

In the past 25 years, Estonian agriculture and society have been subject to significant reforms and institutional changes. These have also affected Estonian dairy farms and dairy processors. Therefore, medium or long term reviews of Estonian agriculture should consider the transition context. This paper aims to review the development of the Estonian dairy sector between 1994 and 2014, and analyse the competitive position of Estonian dairy farms and its dairy processing industry from various perspectives[2]. First, the theoretical frameworks applied in the studies of competitiveness are reviewed. Second, the institutional, policy and market context is reviewed, with the aim of providing the background for the development of the dairy sector. Third, the development and competitiveness of milk production and dairy processing is analysed. Fourth, the trends in the domestic demand of dairy products are reviewed. Fifth, the foreign trade performance of the main classes of dairy products is studied. In the discussion and conclusions section, the interrelations between the competitiveness of Estonian dairy farms and the dairy processing industry, institutional, policy and market contexts, domestic demand and foreign trade performance are considered.

Theoretical framework of competitiveness

Measuring the competitiveness of the dairy sector has been an important research topic for many authors and it has been analysed from various standpoints (Thorne, 2004; Fertő, Hubbard, 2003; Dillon *et al.*, 2008, Donnellan *et al.*, 2009; Tacken *et al.*, 2009; Omel, Värnik, 2009; Van Berkum, 2009; Latruffe, 2010; Latruffe, 2014; Jansik *et al.*, 2014; Jedik *et al.*, 2014; Irz, Jansik, 2015). Competitiveness is a relative, complex, multidimensional and undetermined concept. Since the general theory of competitiveness is non-existent and there is no single definition (Ahearn *et al.*, 1990; Sharples, 1990), different interest groups define competitiveness differently, thereby sometimes misusing the concept. The authors mostly agree that a competitive firm must be able to offer products that meet the market demand (in terms of price, quality and quantity), ensuring, at the same time, adequate profit or an increase in the market share in its home country or abroad (Martin *et al.*, 1991; Smit, 2010; Vuković *et al.*, 2012; Jansik *et al.*, 2014).

The structure-conduct-performance paradigm (Figure 1), being descriptive and providing an overview of industrial organisation, is one of the frameworks applied in the competitiveness studies (Van Berkum, 2009).

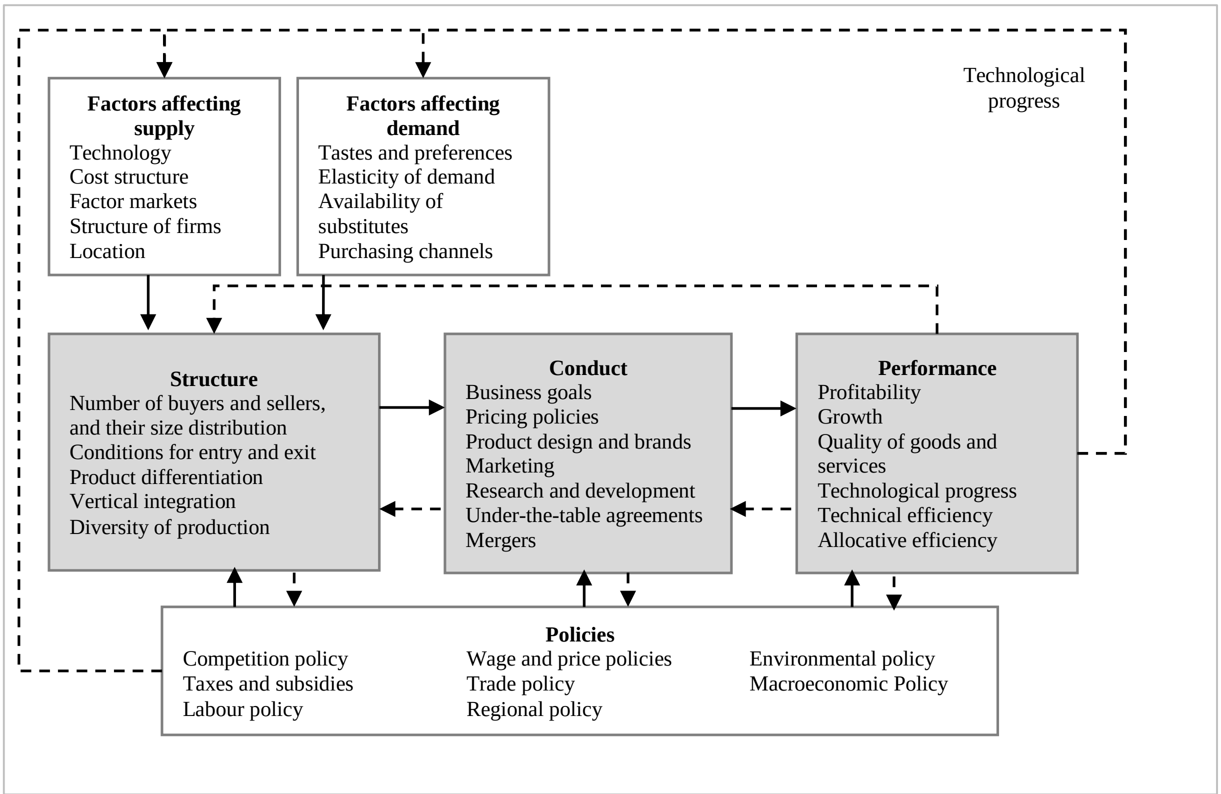

Figure 1. The framework of the structure-conduct-performance paradigm. Source: Lipczynski *et al.* (2005)

[2] The first five years of transition are not included due to the incompatibility of data. Estonian independence was restored in 1991; therefore, the data from 1990 reflects Soviet Estonia, which had a command economy and the currency of the Soviet Union. In addition, in the beginning of the 1990s, Estonia had a very high inflation rate. Therefore, the monetary data from the beginning of the transitional period is not easily comparable with later periods.

According to this approach, an industry's performance (success) depends on the conduct (behaviour) of its firms, which in turn depends on the structure of the industry. The industry's structure depends on the basic conditions, such as the factors that affect supply (technology) and demand. Government policies also have an important role in this framework, as they affect both sellers and buyers in the market (Carlton, Perloff, 2015).

Competitiveness can be evaluated from various perspectives. Bojnec and Fertő (2014) conclude that competitiveness can be analysed at three levels: national (macroeconomic), industrial (branch) and firm (microeconomic) level. There are different approaches to analysing competitiveness such as traditional trade theory, industrial organisation theory and strategic management theory (McCalla, 1994; Garcia Pires, 2010; Donnellan *et al*., 2011; Gapšys, 2013). Reimer and Stiegert (2006) studied several aspects in international competition based on the strategic trade approach. It has been suggested that the trade theory based approach is essentially a supply-side approach to competitiveness, where relative price differences have remained the main indicators of competitiveness. From the industrial organisation theory point of view, it is possible to define the variables affecting the company's economic situation (Figure 1) and estimate their respective effects (Van Duren *et al*., 1991; Shatrevich, 2014). Efficiency and value added through cost management and product differentiation are characteristics that define competitiveness from the strategic management theory point of view (Kennedy *et al*., 1997).

Some authors emphasise that each company can gain a competitive advantage over its competitors in some attributes for a short period, but it is highly improbable that it can hold its superiority for a longer period (Kennedy *et al*., 1997). Therefore, in order to maintain competitiveness, it must be periodically analysed and respective corrective actions must be taken. In addition to such traditional competitive advantages as the availability of inputs and price efficiency, demand for the product, the company's strategy, the overall development of the sector and government actions are also important. There is no consensus as to the importance of defining the sources of competitiveness; some authors think that defining the sources of competitiveness is crucial because they are directly related to measuring competitiveness and its indicators (Buckley *et al*., 1988; Thorne, 2004). It is believed that an ideal combination of competitiveness indicators will provide a good overview of the competitiveness of a company, branch of industry or country. However, it is necessary to distinguish between the different stages in the measurement of competitiveness. Competitiveness indicators measure the competitiveness of the company, whereas competitive potential measures its sources. The process of competition, on the other hand, finds expression in how the competitive potential is transferred into competitiveness.

Competitiveness has been found to be closely linked to productivity, a parameter characterising the efficiency of the process, and measuring the conversion of inputs into outputs. Several authors have used partial productivity indicators to measure competitiveness (Latruffe, 2010; Jansik *et al*., 2014; Irz, Jansik, 2015). However, without taking into account production costs or profitability indicators, a low partial productivity indicator does not necessarily mean low competitiveness potential, as low production costs can compensate for low partial productivity. For example, high labour productivity may reflect high efficiency resulting from a better use of technology. However, it may also be caused by substituting inefficient capital for labour. Therefore, partial productivity indicators do not adequately characterise the company's competitiveness. To reduce this shortcoming, the total factor productivity (TFP) indicator, which combines all inputs and outputs used in production, is used (Jansik *et al*., 2014; Kimura, Sauer, 2015; Irz, Jansik, 2015).

In addition to the competitiveness of an individual company, the competitiveness of the entire value chain, which may be based on trade, and terms of trade, may prove the determining factor. Comparative advantage in domestic production in the areas where the opportunity costs are lower or equal to international prices is an important factor that affects competitiveness. Therefore, countries specialise in such lines of production where they are able to keep the opportunity costs low. It has been suggested that in order to determine the specialisation of a country it is important to take account of the comparative advantage as, due to lower costs, it makes it possible for the country to increase the production for export (Houck, 1992). Therefore, trade based on comparative advantage ensures a more efficient resource allocation in the economy. Competitive advantage is sometimes used as a synonym of comparative advantage. It is suggested, however, that competitive advantage is mainly a political concept, giving the sector a trade advantage through grants/subsidies, tax incentives, trade restrictions or other interventions in the country (Jeffrey, Grant, 2001). Consequently, in order to determine what a country is expected to produce for export, both the comparative and the competitive advantage are taken into account. Omel and Värnik (2009) suggest that price and quality are the two main factors that determine the competitiveness of products both in domestic and export markets. Lower production costs provide a competitive advantage in (lower) price, while better quality, an attractive brand or additional benefits attract consumers to pay a higher price for the product.

According to Balassa (1965), the revealed comparative advantage expresses the successfulness of the trade performance of the country. It is assumed that the structure of international trade describes both the relative costs of production and non-price factors. One of the most important factors that determines the structure of international trade is comparative advantage. According to the theory of comparative advantage, a country will specialise on the production of products with comparative advantage and will export these products and import products with comparative disadvantage. Therefore, by comparing exports and imports of the products belonging to the same commodity group the advantage in production of specific products can be described.

In the following, an eclectic approach (Van Berkum, 2009) is used, *i.e*. the competitiveness of the Estonian dairy sector in the period 1994–2014 is analysed from different perspectives. First, the policy context and accompanying effects on institutional and market context is reviewed. The competitiveness of milk production and milk processing is discussed in light of partial productivity measures, literature on total factor productivity change in Estonian dairy sector and growth rates of milk production and processing. In addition, the structure of dairy farms is considered. Demand is analysed from two perspectives: domestic and export markets. Competitiveness in export markets is discussed based on the revealed comparative advantage indices.

Institutional, policy and market context

The development of the Estonian dairy sector in the last 25 years has been affected by the institutional changes at the beginning of the 1990s, changes in agricultural policy and world markets. In Figure 2, the developments of the Estonian producer price of milk in the period 1992–2013 are compared to the prices in Germany and New Zealand. The German producer prices of milk are considered an indicator of the European Union's (EU) average prices, which are affected by the EU agricultural policy and world market prices. New Zealand, a country where the effects of market distorting policies are relatively low (in the EU, the average Producer Support Estimate (PSE) in 1992–1995 was 35%, while in New Zealand the average PSE in 1992–1995 was 1% (OECD, 2014), is considered a representative of the world market price level.

In 1992–1995, major reforms related to regaining the independence of the Republic of Estonia were initiated, resulting in the establishment of new production structures (private farms and agricultural enterprises), free trade, the disappearance of former markets and subsidies (Viira *et al*., 2009; Viira, 2014). During this period, the Estonian government decided to follow a liberal economic policy, which had a detrimental effect on the agricultural sector (Unwin, 1997). The liberal trade policy opened the Estonian market for subsidised agricultural and food imports from other countries, resulting in PSE estimates of –89% in 1992, –10% in 1994 and 0% in 1995 (OECD, 2002; Estonian Ministry of Agriculture, 2003). From Figure 2 it stems that during this period the producer prices of milk in Estonia were an average of 30% below the price level in New Zealand, and markedly (70%) lower compared to German prices.

In 1996–2001, the scope and budget of Estonian agricultural policy increased. After the adoption of the action plan for becoming an EU member in 1996, the agricultural policy was developed so that it would harmonise with the EU's Common Agricultural Policy (CAP) at the time of accession. Direct payments were implemented and legislative provisions for applying import licences and tariffs were adopted. However, foreign trade remained liberal (Viira *et al*., 2009; Viira, 2014). From Figure 2, it appears that Estonian producer prices of milk in this period were similar to prices in New Zealand, while German prices were declining but remained at nearly 100% higher level compared to New Zealand and Estonia.

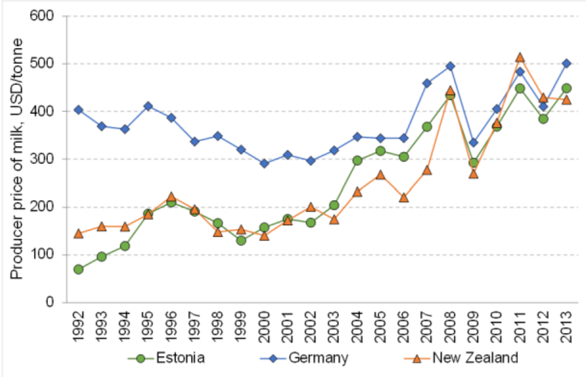

Figure 2. Producer price of milk in Estonia, Germany and New Zealand in the period 1992–2013. Source: Faostat (2015)

On 1 May 2004, Estonia became an EU member and applied the CAP with direct payments, milk quotas, export subsidies, EU import licences and tariffs, intervention stores, private storage aid, investment subsidies and other measures. From Figure 2, one can notice that the EU accession raised milk producer prices in Estonia by about 25% compared to prices in New Zealand. This implies the effect of the policy change (EU accession) on the milk prices in Estonia. However, in 2004–2008, Estonian producer prices of milk remained an average of 13% lower compared to prices in Germany.

However, the policy context in the EU is not constant. Since 2008, the world market prices have been at higher levels compared to the previous decades, and the EU's CAP has become more market orientated, deregulating the dairy market and lowering price supports in dairy product supply chains (Bojnec, Fertő, 2014; European Commission, 2015a). The EU average PSE declined from 31% in 2005 to 20% in 2013 (OECD, 2014). Therefore, the differences between the German (EU), Estonian and New Zealand price levels have decreased. In 2008–2013, Estonian producer prices of milk comprised 98% of the prices in New Zealand and 90% of the German prices, on average. On 1 April 2015, the EU's 31-year-old milk quota system was abolished and the EU milk producers entered into a policy environment with even less market regulation and more (world) market orientation (European Commission, 2015a).

Following higher world market prices compared to previous decade, the gradual increase of milk quotas from 2008 and the elimination of milk quotas in 2015 (European Commission, 2015), farmers in many EU member states increased milk production. In 2008–2014, milk production in the EU28 member states increased by 10.5 million tonnes (7.1%). However, the distribution of the growth is uneven across the member states. Figure 3 depicts the relative growth in number of dairy cows and average milk yields in the period 2008–2014. Balloons that represent EU member states indicate volume of milk production in 2008. The dotted line represents iso-production curve, indicating how much the milk yield should increase or decrease in order to maintain the constant milk production volume if the number of dairy cows decreases or increases. In 2008-2014, the total number of dairy cows in EU28 member states decreased by 846,000 (3.5%). The number of dairy cows increased in seven EU member states: Italy (by 13.0%), Ireland (10.1%), Cyprus (7.3%), Luxembourg (1.9%), Germany (1.8%), Netherlands (1.4%), and Austria (1.4%). The most noteworthy of these member states are Germany, Italy, Netherlands and Ireland, since these countries contribute a significant part (39.4%, in 2014) of total EU milk production. These countries could be regarded as competitive milk producers with a high impact on the EU dairy market.

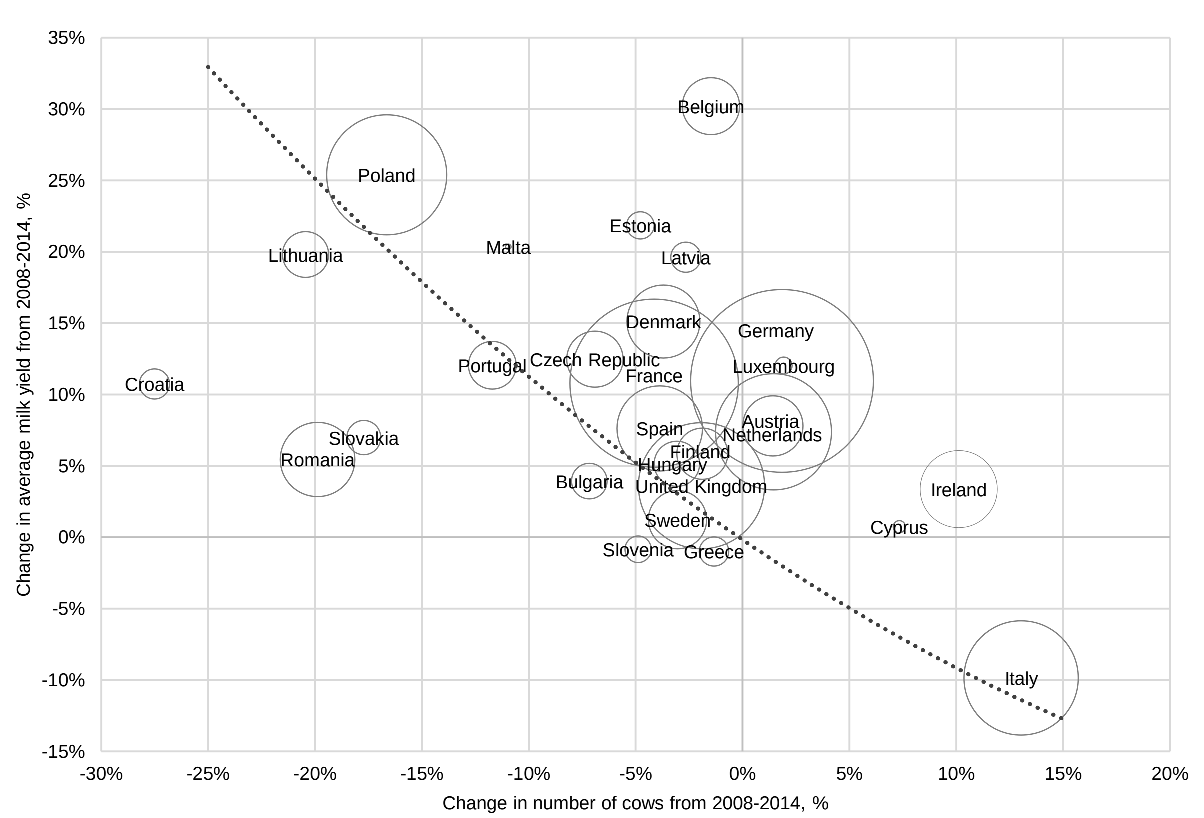

Figure 3. Changes in number of dairy cows and average milk yield per cow in the EU countries in the period 2008–2014. The size of the balloons indicate volume of milk production in 2008, while the dotted line indicates the iso-production curve. Source: Eurostat (2015)

In 2008–2014, milk production declined in nine EU member states: Croatia (by 36.1%), Romania (15.5%), Slovakia (12.0%), Slovenia (5.7%), Lithuania (4.7%), Bulgaria (3.5%), Greece (2.3%), Sweden (1.8%) and Portugal (1.1%). From the point of view of the Estonian dairy sector, the decrease in milk production in Lithuania and Sweden are more relevant, since these markets are closer, and Lithuania is one of the most important trading partners for the Estonian dairy sector. In 2008–2014, the number of dairy cows decreased by 4.8% in Estonia, average milk yield increased by 21.9% and total milk production increased by 16.0%. Therefore, as illustrated by the distance between the centre of the Estonian balloon and the iso-production curve in Figure 3, the relative growth in milk production in Estonia was one of the quickest in the EU, being third after Belgium (28.3%) and Latvia (16.4%).

Milk production

Milk production could be considered as an identity of the number of dairy farms, average number of dairy cows per farm and average milk yield per cow. After regaining independence, milk production in Estonia declined significantly. In 1992–1996, milk production decreased by 26.6% from 919.3 to 674.8 thousand tonnes (Figure 4). In the beginning of the period, the producer prices of milk in Estonia were below the prices in New Zealand, which could be considered a proxy of world market prices (Figure 2). This was due to the liberal trade policy without tariffs and non-tariff trade barriers (Viira *et al*., 2009; Viira, 2014). In 1992–1994, Estonian producer prices of milk ranged from 48–74% of the price level in New Zealand. At this price level, many of the dairy farms were unable to continue production, the number of dairy cows decreased by 32.3% and the average milk yield per cow stagnated at average 3,474 kg/cow between 1992 and 1995 (Figure 4).

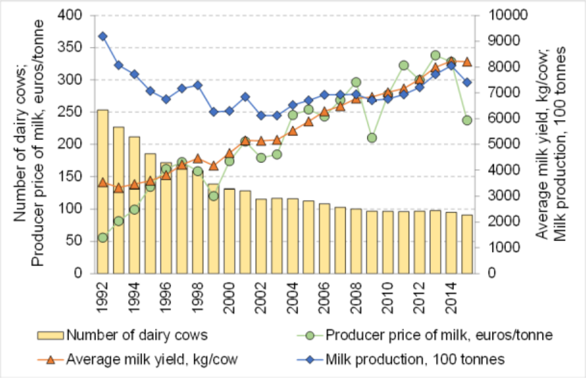

Figure 4. Number of dairy cows, average milk yield, milk production and producer price of milk in Estonia in the period 1992–2015. Source: Statistics Estonia (1996, 1998, 2000, 2001, 2015)

*Figures for 2015 are forecasted based on data from 9 months

Estonian producer prices of milk reached the New Zealand price level in 1995. Since then, the producer price of milk in Estonia has followed the trends in the world market; it has affected the number of dairy farms, number of dairy cows and milk yields, therefore determining the total milk production. In 1996–1998, production recovered: in 1998, production exceeded the 1996 production levels by 8.1%, while the number of dairy cows decreased by 7.6% and average yield improved by 17.0%. At that time, Estonian producer prices of milk ranged from 94–112% of New Zealand prices.

The next drop in milk production occurred in 1999 when the producer price of milk decreased by 23.8% compared to 1998. The crisis was initiated by multiple events in the second half of 1998: the decline in dairy prices on world market, problems on the Russian export market, excessive precipitation that caused some of the harvest to fail and problems in the Estonian financial sector (Ministry of Agriculture, 1999). Because of the significant reduction in the milk price, in comparison to 1998, the number of dairy cows decreased by 12.7%, average milk yield per cow decreased by 6.4% and milk production decreased by 14.2%.

In 2000 and 2001, milk prices recovered, and while by 2001, compared to 1999, the number of dairy cows had declined by 7.1%, milk yields exceeded the 1999 level by 23.5%. Therefore, milk production in 2001 exceeded the 1999 level by 9.2%. The third drop in milk production occurred in 2002 because of the decrease in world market prices and unfavourable weather (drought) (Ministry of Agriculture, 2003). In 2002, the producer price of milk decreased by 12.4% compared to 2001, the number of dairy cows decreased by 10.1%, average milk yield by 0.3% and milk production by 10.6%.

In 2003–2008, milk producers experienced a favourable period with increasing milk prices and increasing subsidies (Figure 5). In 2004, Estonia became an EU member. The EU accession changed Estonian agricultural policy. Estonia entered the more protected and subsidised EU common market. Therefore, producer prices increased, farm payments increased and farmers had better access to investment subsidies. In addition, the access to credit improved, which in turn facilitated investments into modern technologies. It has been estimated that new cowsheds were built or old ones renovated in 182 dairy farms between 2001 and 2011. Therefore, at least 60% of Estonian dairy cows are in modern cowsheds equipped with modern technologies (Viira *et al*., 2011). In specialised dairy farms between 2004 and 2008, total subsidies (excluding subsidies on investments) per dairy cow increased from 397 to 729 euros (83.4%) and fixed assets (excluding land, permanent crops and quotas) per dairy cow increased from 3,222 to 5,240 euros (62.7%). In 2003–2008, the number of dairy cows decreased by 14.0%; however, milk yields improved by 31.0% and milk production increased by 13.5%. In 2003–2008, Estonian milk producer prices amounted to 117–133% of the New Zealand price level. In Estonia, not a single year before and after this period has seen such favourable producer prices of milk compared to New Zealand, and such high average subsidy levels per dairy cow and kg of produced milk.

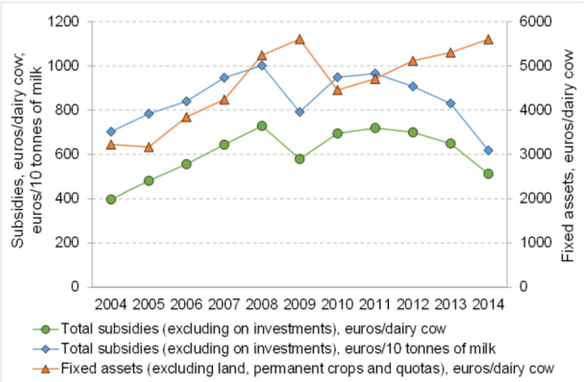

Figure 5. Total subsidies and fixed assets in specialised dairy farms (FADN farm type 45) in Estonia in the period 2004–2014. Source: FADN Public Database (2015) (years 2004–2012); Rural Economy Research Centre (2015a) (years 2013–2014)

The fourth price shock that induced the reduction in milk production occurred in 2009 when the producer price of milk dropped by 29.1% (by 86.3 euros/tonne) compared to 2008. The number of dairy cows decreased by 3.7% and milk production decreased by 3.3%. Average milk yield did not decrease, but the growth rate slowed down to 0.8% compared to the previous year. The price shock coincided with the economic crisis, due to which, the government reduced additional top-up payments and the average subsidy level per dairy cow decreased by 150 euros and per tonne of milk by 21.0 euros. The cut in subsidies amplified the effects of the milk price and economic crisis for Estonian dairy producers.

From 2010 to the first half of 2014, milk producers faced another period with comparatively favourable milk prices. In 2010, the average subsidy level per dairy cow recovered to 95.2% of the 2008 figure. Since the

EU further liberalised the dairy market, the price difference between Estonian and New Zealand producer prices diminished. In 2010–2012, the Estonian producer prices amounted to 87–98% of the prices in New Zealand. Since 2008, the abolition of milk quotas was anticipated as a result of the CAP "Health Check" (European Commission, 2015a) and farmers even increased production in 2012, when there was a short-term (8 months) decline in the producer price of milk. In 2011–2013, the number of dairy cows increased by 1.8%, the first such increase since 2003. In 2010–2013, milk yields improved by 13.8% and milk production increased by 14.2%.

The fifth shock in milk prices occurred in the second half of 2014, after Russia announced an import ban on 6 August (European Commission, 2015b). After that, the producer prices of milk fell to 250 euros/tonne and below. While, due to the favourable prices in the beginning of the year, the average milk producer price was 328 euros/tonne in 2014, the average price in the first nine months of 2015 was 237 euros/tonne, which is 27.7% lower. Because of the low prices, the number of dairy cows declined by 4.8% in the first nine months of 2015, average milk yield declined by 0.1% and milk production declined by 5.0% compared to the same period in 2014. Another reason behind the reduction of milk production in the beginning of 2015 is related to the milk quota. In the last quota year of 2014/2015, Estonia for the first time exceeded the national milk quota by 1.2% (ARIB 2015). Due to the low milk prices, milk producers were in a critical economic situation as it was; therefore, many of them reduced production in order to avoid exceeding the quota and paying the super levy. As was the case in the 2009 crisis, the sharp decline in milk price in 2014 was accompanied by a reduction in average subsidy level. Compared to 2013, the average subsidy level per tonne of produced milk cow declined by 21.2 euros in 2014. However, though the economic crisis was the reason behind the reduction of subsidies in 2009, in 2014 the reasons were political and related to the changing priorities of the new coalition and government.

Therefore, the decreases in Estonian milk production have mainly been caused by various market shocks, but agricultural policy has also played a role. In 1992–1996, the shock was related to institutional changes and the free market, accessible to subsidised exports from other countries that reduced Estonian milk producer prices below world market (New Zealand) averages (Figure 2). From 1997 onwards, the price shocks have been related to changes in world market prices. From Figure 4, it appears that the milk price decrease in 2009 and 2012 did not cause a significant decrease in milk production. This could be explained by higher subsidies compared to the period before EU accession, which helped sustain producers during the period when prices were low. It can also be explained by the changes in farm structures over time, as less competitive farms have left the sector during previous crises and the majority of those that have remained are competitive in the current world market context. However, the 2014–2015 crisis may be more severe. In addition to poorer market conditions, there has been a major policy change with the removal of milk quotas and reduction of average subsidy level in Estonia. Therefore, there are uncertainties about future price levels following the crisis.

Structure of dairy herds

According to the structure-conduct-performance paradigm, the structure of firms is one determinant of supply and therefore a determinant of performance (competitiveness) of the industry. In Northern Europe, the general tendency is towards larger average dairy farms. According to Jansik *et al*. (2014), in Denmark and Estonia, the share of dairy cows in farms with 100 cows and over in 2010 was highest among the EU countries surrounding the Baltic Sea. At the same time, in Poland, Lithuania and Latvia, the percentage of dairy cows kept in small farms was the highest. Jansik *et al*. (2014) conclude that in more concentrated dairy sectors, the transaction costs are lower and the lower transaction costs contribute to the better competitiveness of such sectors. Larger dairy farms were also found to be better performing in Estonia by Kimura and Sauer (2015).

Table 1 gives an overview of the changes in a number of dairy herds in different size classes between 1993 and 2015. It has to be noted that Table 1 is based on the data of dairy herds in milk recording, but milk recording is not mandatory; therefore, not all the dairy herds participate. However, the advantage of milk recording data is in a longer time frame and more detailed information about different size classes. In 2014, 95.9% of Estonian dairy cows were under milk recording. From Table 1, one can note that the number of dairy herds declined by 82.1% between 1993 and 2015. The decrease has been largest (both in absolute and relative terms) in herds of 1–10 cows (–93.9%) and 101-300 cows (–72.2%). In the first case, small family farms have exited during the transition and after the EU accession (Viira, 2014). In the beginning of the 1990s, farms with 101–300 dairy cows were probably successors of privatised former collective and state farms (or parts of these). The large decline of herd numbers in this size class could be explained by the inability of farmers to cope with the free market reality of the 1990s (Viira *et al*., 2009; Viira, 2014) and the phenomena of the "disappearing middle" (Munton, Marsden, 1991). Data from November 2015 suggests that the decline in small farms groups continues due to the recent crisis in dairy markets. During the crisis, from 2014 to November 2015, the size classes where the number of herds has not changed or has increased are 51–100 cows (small family farms), 301–600 cows (both family farms and enterprises), 901–1,200 cows (large-scale enterprises) and >1,200 cows (large-scale enterprises).

Table 1. Number of dairy herds in different size classes under milk recording in the period 1993–2015

Year	Farm size class, number of dairy cows								Total
	1–10	11–50	51–100	101–300	301–600	601–900	901–1200	>1200	
1993	2,815	291	161	342	120	27	6	5	3,767
1995	2,128	291	127	278	74	14	5	3	2,920
1997	1,685	484	116	240	67	13	4	3	2,612
1999	1,832	682	116	188	60	12	4	3	2,897
2001	1,958	716	103	173	52	15	2	4	3,023
2003	1,727	637	103	164	60	13	4	4	2,712
2005	1,122	585	91	155	62	13	3	5	2,036
2007	489	465	100	135	63	17	4	3	1,276
2009	346	375	95	122	61	17	4	4	1,024
2011	273	314	93	110	63	17	3	6	879
2013	210	277	75	107	58	25	6	6	764
2014	176	256	78	108	53	24	8	6	709
2015 November	172	229	90	95	58	15	8	7	674
Change in 1993–2015	–93.9%	–21.3%	–44.1%	–72.2%	–51.7%	–44.4%	33.3%	40.0%	–82.1%

Source: Yearbooks of Estonian Livestock Performance Recording Ltd.

Figure 6 depicts the proportion of total milk production in different size classes between 1994 and 2014. One can note that the six largest dairy farms (according to Estonian Livestock Performance Recording, 2015) produced 12% of total milk production in 2014, while the 14 largest dairy farms produced 21% of total milk and the 38 largest companies produced 41% of Estonian milk. Farms with 1–10 dairy cows produced 1% of total milk, farms with 11–50 cows 6% and farms with 51–100 cows 5% of total milk in 2014. Therefore, farms with 100 or fewer cows contributed just 11% of total milk production.

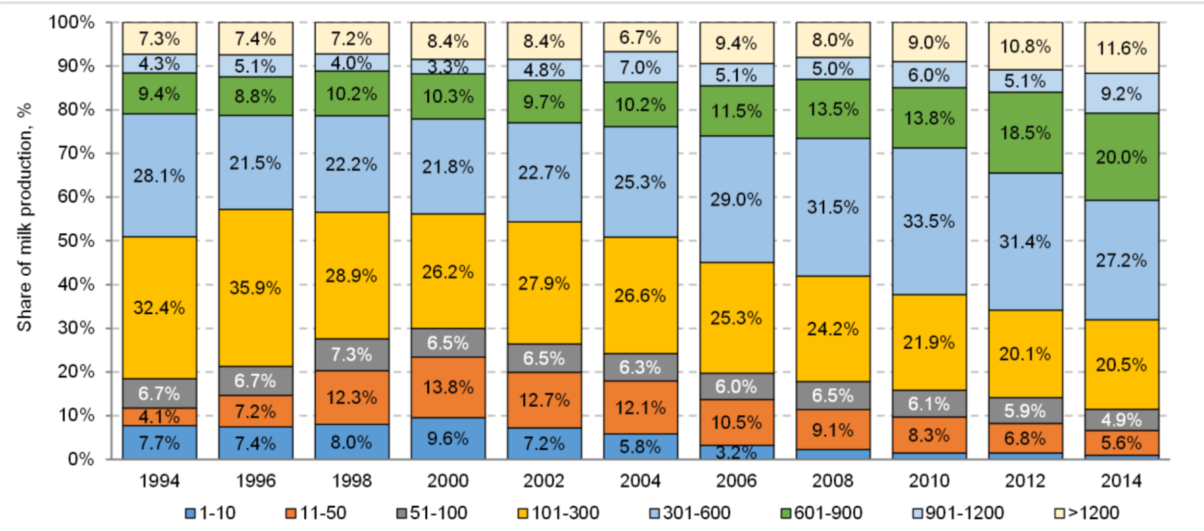

Figure 6. Share of milk produced in herd size classes in the period 1994–2014. Source: Yearbooks of Estonian Livestock Performance Recording Ltd

There has been also a significant change in the structure of breeds. In 1990, 49.1% of dairy cows were Estonian Red and 50.7% were Estonian Holsteins, but by 2014 the shares of both breeds were 20.0% and 79.1% respectively (Estonian Livestock Performance Recording, 2015). As a result of the increase in the significance of large dairy farms, where cows are kept indoors all year round, and change in the structure of dairy breeds, the seasonality of Estonian milk production has significantly decreased. In 2003, milk collection in the highest volume month (June) exceeded the lowest volume month (November) by 1.40 times. In 2014, the peak-to-low ratio was 1.18 (Statistics Estonia, 2015). In Lithuania, in 2014, the peak-to-low ratio of milk collection was 1.67, and in Latvia 1.47 (Eurostat, 2015). The lower seasonality of milk collection is a factor that makes the processing of Estonian milk more efficient because the processing industry can utilise their capacity more evenly throughout the year.

Milk yield

Average milk yield per dairy cow is the most common productivity measure of dairy farms. In 2001–2014, average annual milk yield per dairy cow among the EU member states increased most rapidly in Estonia (by 58.3%), Lithuania (by 46.7%) and Latvia (by 44.4%) (Eurostat, 2015). From Figure 7, it appears that among the selected countries, Estonian average milk yield per cow was third highest in 2014, and the yield growth outpaced the other countries. While average milk yield could be regarded as the most common productivity indicator, it should be remembered that it is a partial productivity measure and does not necessarily reflect the total factor productivity of dairy farms.

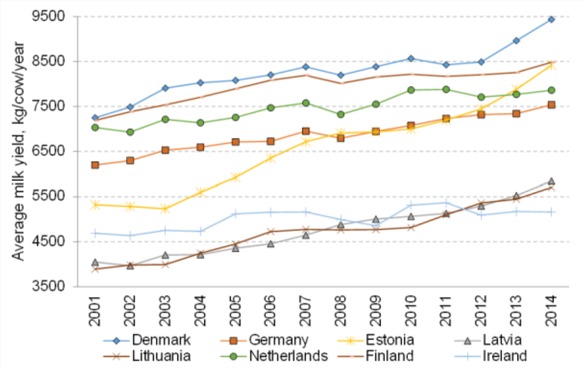

Figure 7. Average milk yield in selected countries in the period 2001–2014. Source: Eurostat (2015)

Rapidly increasing and high average milk yield has been the pride of the Estonian dairy sector, indicating the high productivity of dairy cows. However, some negative trends accompany the positive trend of increasing milk yield. In 2001–2014, the average milk yield per cow in the herds that were under milk recording increased by 59.0% to 8,728 kg/cow/year (Figure 8). At the same time, the average life span of dairy cows decreased by 1.6 years. While the average age at the first calving decreased by 0.3 years, the average productive time (from first calving to culling) decreased by 1.3 years (29.9%). Nonetheless, Riisenberg (2012) found that the low average productive time of dairy cows does not have a significant negative effect of farm profits considering the (low) price of in-calf heifers and high milk yield.

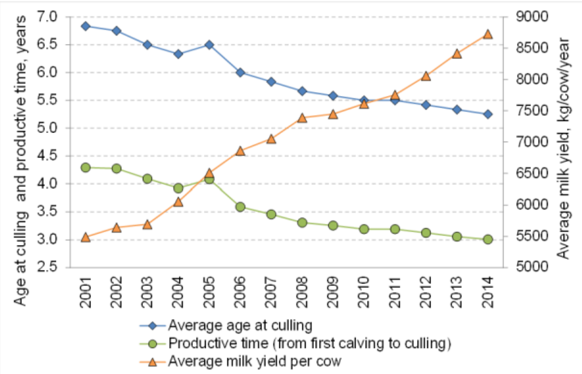

Figure 8. Average milk yield, age at culling and productive time in herds under milk recording in the period 2001–2014. Source: Estonian Livestock Performance Recording Ltd. (2015)

Still, at least two aspects of this trend require further consideration. Decreasing the productive time of dairy cows results in fewer calves per cow's lifetime. Since 52% of the calves are male and 48% female (Estonian Livestock Performance Recording Ltd., 2015), the number of alternatives for selecting replacement heifers is declining. In the longer term, this could undermine the quality of the stock of Estonian dairy cows. The other aspect relates to the more short-term effects on farm revenues. The shorter life span of dairy cows means that there are fewer opportunities for selling (in-calf) heifers. Therefore, the revenue from selling heifers declines. Kimura and Sauer (2015) found that livestock output declined by 7.2% per annum in Estonian dairy farms between 2003 and 2012, thereby reducing the aggregated output growth measure. Luik *et al.* (2014) found that in the group of farms with highest technical efficiency the average age of dairy cows at culling was higher than in the group of farms with medium technical efficiency. In periods of high milk prices, this does not pose problems for dairy farmers. In periods of low milk prices, however, the revenue from selling heifers is a very important additional stream of income for farmers. In 2005–2013, beef contributed an average of 6.9% of the total output of Estonian specialised dairy farms; however, the value of beef constituted an average of 46.5% from farm net income[3]. In 2009, when milk prices were low, the value of beef amounted to 109.6% of farm net income (FADN Public Database, 2015). This implies that while beef contributes a relatively small proportion of total farm output, the changes in its value have a much more significant impact on net farm income. Therefore, *ceteris paribus*, increasing the average life span of dairy cows could improve farm profits in the short term, while improving the selection of heifers for herd replacement in the long term.

While historically, milkfat (for making butter) was the component of milk of most commercial value, nowadays milk protein (for making cheese and whey products) attracts the greater value (Augustin *et al.*, 2013). Similarly, the analysis by Põldaru *et al.* (2010) indicate that the variation in cheese prices have larger effect on producer price of milk, compared to butter prices. The trends of Estonian average milk fat and protein content follow this pattern. In 2003 to 2013, along with the rapid increase in milk yields and the increase of the percentage of Estonian Holstein cows[4], the average fat content of milk decreased by 0.14 percentage points (by 3.4%) to 3.99% (Figure 9). At the same time, the average protein content of milk increased by 0.12 percentage points (by 3.7%) to 3.37% (Eurostat, 2015). Though the increase in milk protein content evens out the decline in milk fat content, and the combined milk fat and protein (milk

[3] Farm net income includes value of total output, balance of current subsidies and taxes, and balance of subsides and taxes on investments, from which total intermediate consumption, depreciation, wages, rent and interests paid are subtracted. This could be regarded as a farm profit before remuneration of own (unpaid) labour (FADN Public Database, 2015).

[4] Milk solids (milk fat and protein) have declined more rapidly in those years when an increase in average milk yield has been high. In 2009, when average milk yield increased by a modest 0.8%, average milk fat content increased by 0.01 percentage points, and average milk protein content increased by 0.02 protein points. The negative effect of increasing milk yield on milk fat and protein content is reported also by Kiiman *et al.* (2013). Estonian Holstein cows have a lower average milk fat and protein content compared to Estonian Red cows. In 2014, the average milk fat content of Estonian Red cows was 4.12%, and that of Estonian Holstein cows was 3.97%. For average milk protein content, the respective figures were 3.43% and 3.35% (Estonian Livestock Performance Recording Ltd. (2015).

solids) content is virtually unchanged, one should consider the Estonian figures in the context of neighbouring and major dairy export countries. From Figure 9, it stems that the average milk fat content in Estonia in 2013 was 0.41 percentage points (9.3%) lower than in the Netherlands and merely 0.05 percentage points (1.3%) higher than in Ireland. However, between 2003 and 2013 the decline in average milk fat content in Estonia was steepest among the EU member states. At the same time, Ireland witnessed one of the largest increases (by 0.21 percentage points and 5.6%) in milk fat content in the EU. However, Latvia witnessed a steep decline (by 0.21 percentage points and 4.9%) in average milk fat content between 2009 and 2013.

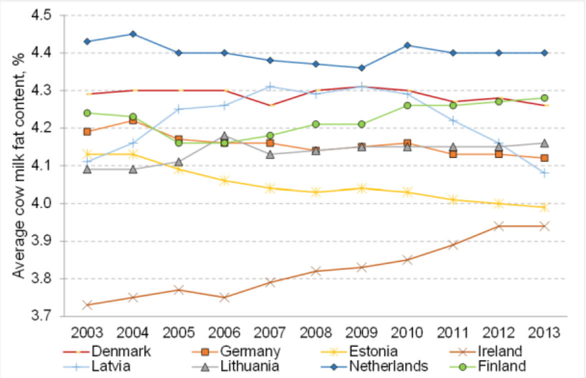

Figure 9. Average cow milk fat content in selected countries in the period 2003–2013. Source: Eurostat (2015)

From Figure 10, it appears that the average milk protein content in most of the observed countries increased between 2003 and 2013. However, the changes have been more modest when compared to the changes in average milk fat content. From the observed countries, the increase in milk protein content in Finland was largest (0.15 percentage points and 4.5%). In Germany and Lithuania, the average milk fat content declined in the observed period by 0.02 percentage points (by 0.6%). In 2013, the protein content of milk was highest in the Netherlands and Denmark (3.53% and 3.52% respectively). Milk protein content was lowest in Lithuania and Latvia (3.25% and 3.26% respectively). Estonian milk protein content exceeded the Lithuanian average by 0.14 percentage points (4.3%). The combined average milk fat and protein content in Estonia in 2013 was 7.36%, while in the Netherlands it was 7.93%, which exceeds the Estonian figure by 0.57 percentage points (7.7%). The Danish aggregated figure exceeded the Estonian measure by 0.42 percentage points (5.7%).

According to Bojnec and Fertő (2014), the Netherlands and Denmark were the EU countries with the highest dairy export competitiveness. High milk yields and milk fat and protein content could be regarded as contributors to the competitiveness of Dutch and Danish dairy chains. While average milk, milk fat and protein yields per dairy cow increased markedly in Estonia, aggregated milk fat and protein content remains lower compared to the Netherlands, Denmark and Finland.

The content of milk fat and protein in milk could affect both the efficiency of farms and the processing industry. Luik *et al*. (2014) found that when milk yield is constant, the higher percentage of milk solids was positively affecting the technical efficiency of Estonian dairy farms. The processing industry pays a higher price for milk with higher milk fat and protein content. However, Riisenberg (2012) concluded that while price adjustment for milk protein content is more significant in comparison to price adjustment for milk fat, price adjustments related to milk content are not sufficient to motivate farmers to maximise milk fat and protein content instead of milk output per cow. Compared to Finnish practice, the price adjustment (measured in Euros per tonne of milk) for 0.1% of fat was 7.5 times lower in Estonia, and price adjustment for protein was 4.1 times lower (Riisenberg, 2012). The quality class of milk, which is related to milk hygiene, has a more significant effect on the producer price of milk. Lower milk solids content implies relatively higher transporttation and processing costs per kg of processed dairy products. Therefore, increasing the content of milk solids in 1 kg of milk (which is not rapidly alterable) would improve the efficiency of the dairy processing industry. One of the more rapid solutions for cheese manufacturers, as suggested by Augustin *et al*. (2013), is to choose milk from specific farms for improved cheese making properties. There could be also long-term solutions to the problem: Vallas *et al*. (2012) found that the genetic improvement of Estonian Holstein cows would have positive effects on milk coagulation properties, and thereby on cheese making. Several factors affect milk fat and protein content, of which feed content (more significant for Estonian Red cows), breeding (more significant in case of Estonian Holstein cows), and the good care of animals are the most important. Milk fat content is more responsive to changes in daily farming practices compared to milk protein content. Breeding provides more scope for increasing milk protein content (Riisenberg, 2012).

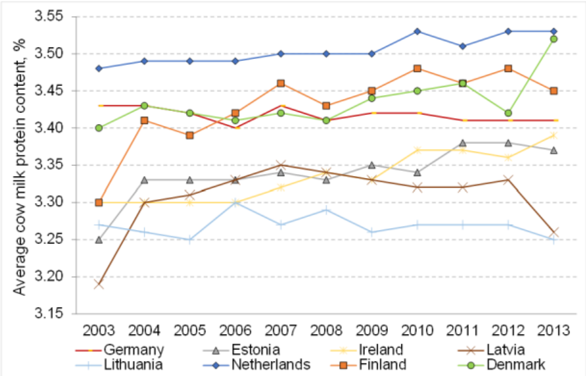

Figure 10. Average cow milk protein content in selected countries in the period 2003–2013. Source: Eurostat (2015)

Productivity of dairy farms

One of the most recent studies on the productivity of Estonian dairy farms (which compared dairy farms in Estonia, the Netherlands and the United Kingdom using farm level FADN data) concluded that the total factor productivity (TFP) declined between 2003 and 2012 on an average Estonian dairy farm by 0.48% per annum, *i.e.* annual growth rates of inputs usage exceeded the annual output growth rates (Kimura, Sauer, 2015). While the output growth in Estonian dairy farms was highest among the three countries, input growth exceeded output growth in Estonia. In the Netherlands and in the United Kingdom, total input usage decreased. In Estonia, the output growth rate (average 4.4% per annum) was reduced by negative growth (on average –7.2% per annum) of livestock output. While the labour usage declined by 7.5% per annum and land usage by 0.6% per annum, growth in inputs such as capital (8.4% per annum), material (6.0% per annum) and service (8.6% per annum) significantly contributed to the average annual growth of 4.6% in total inputs. However, the market share weighted average TFP growth in Estonian specialised dairy farms was 0.85% per annum, indicating diverging productivity growth rates in large, middle and small farms. TFP growth was positively affected by the number of dairy cows, milk yield and stocking density, implying that the main driver of productivity growth in Estonian specialised dairy farms was size expansion and increasing milk yield in a relatively small number of large farms (Kimura, Sauer, 2015).

Previous studies show mixed results regarding the productivity and competitiveness of Estonian dairy farms. Research by Vasiliev *et al*. (2011) found negative productivity growth in Estonian dairy farms for 2001–2003 and 2004–2006. They suggest that the increase in capital input was not harnessed in the best possible way, while average milk yield and production intensity positively contributed to productivity growth. The positive effects of milk yields on the technical efficiency of dairy farms were reported by Luik *et al*. (2011), Põldaru and Roots (2014) and Luik *et al*. (2014). Jansik *et al*. (2014) found (based on aggregate FADN data) that TFP in Estonian dairy farms increased by average 2.5% per annum between 2004 and 2010. Omel and Värnik (2009), based on the domestic resource cost analysis, concluded that both small and large scale producers had a competitive advantage in milk production in the 2001–2006 period. However, large-scale producers were more competitive and, over time, the competitiveness of Estonian milk producers was declining.

Processing industry

Milk production and processing are two segments of the same value chain. Therefore, to a great extent, their competitiveness is interdependent. However, the phenomenon of raw milk trade (Jansik *et al*., 2014) has emerged in recent years, and this could be regarded as an indicator of the competitiveness of milk production and/or the manufacturing of dairy products. From Table 2, it appears that the raw milk trade increased in most of the observed countries. The relative significance of raw milk trade is largest in the Baltic countries. In 2014, in Estonia, the net export of raw milk amounted to 25.2% of collected milk. In Latvia, the figure was 28.0%. At the same time, Lithuania is a net importer of raw milk. In 2014, raw milk import amounted to 18.7% of milk collection and 15.8% of milk processed. Raw milk exports from Estonia and Latvia to Lithuania achieved a significant volume in the past 10 years, and it accelerated following the milk market crisis in 2009. However, it appears that the net import of raw milk decreased in Lithuania in 2014 and the volume of milk processed increased in Latvia and in Estonia. It is too early to conclude that the trend of increasing raw milk exports from Estonia and Latvia to Lithuania has changed and has been replaced by increase in the processing the milk within the borders of the countries where it is produced. From the rest of the observed countries, the raw milk trade is more significant in Ireland, which imports 6.2% of the milk that is processed. In Finland, raw milk trade is negligible, while Denmark and the Netherlands export 3.6% and 2.5% of collected raw milk, respectively. Germany is a raw milk importer, though raw milk imports amount to just 1.5% of processed milk volume.

Growth rates are another indicator by which to compare the development of milk production and processing (Jansik *et al*., 2014). In regard to Latvia and Estonia, the divergence between the relative change in milk collection and processed milk volume in the 2004–2014 period is largest among the observed countries. In the case of Lithuania, the milk processing volume increased by 49.7%, while milk collection increased by 26.1% and milk production declined by 2.7%. In the Baltic countries, there is still some room for increasing milk collection without increasing milk production. While more than 96.9% of produced milk is delivered to the processing industry in Germany, Netherlands, Denmark, Finland and Ireland, the percentage of milk collected amounts to 80.1% in Lithuania, 83.0% in Latvia and 90.7% in Estonia. Based on the figures of raw milk trade and growth rates of milk collection and processing, one could conclude that milk production in Estonia and Latvia developed more quickly than milk processing in the 2004–2014 period, and therefore the competitiveness is better in this segment of the supply chain; in Lithuania, however, the situation is opposite.

Public data for calculating the productivity characteristics of the dairy processing industry is not as rich as in case of dairy farms. In Table 3, labour productivity figures are given for manufacturers of dairy products for 2008–2013 period. For that, the production value is divided by the number of employees, resulting in the production value per employee. Following the approach suggested by Jansik *et al*. (2014) in relation to the labour productivity of dairy farms, this figure is divided into two components – volume (tonnes) of milk processed per employee and production value per kg of milk processed – as described by the following equation:

$$\frac{V}{L} = \frac{Q}{L} * \frac{V}{Q},$$

V denotes production value, L denotes number of employees and Q stands for quantity of processed milk.

Table 2. Milk production, collection, processing and raw milk trade balance in the period 2004–2014

Country	Trait	2004	2006	2008	2010	2012	2014	Change, 2004–2014
Estonia	Milk production, 1000 t	651.9	691.5	693.6	675.4	720.7	804.8	23.5%
	Milk collection, 1000 t	536.1	605.9	605.9	621.1	649.1	730.0	36.2%
	Percentage of collected milk, %	82.2%	87.6%	87.4%	92.0%	90.1%	90.7%	10.3%
	Raw milk trade balance[a], 1000 t	3.3	–57.6	–55.6	–62.5	-159.2	-184.0	
	Milk processed[b], 1000 t	539.4	548.3	550.3	558.6	489.9	546.0	1.2%
	Ratio of processed to collected milk	100.6%	90.5%	90.8%	89.9%	75.5%	74.8%	–25.7%
Latvia	Milk production, 1000 t	784.0	812.1	832.1	830.9	870.6	968.9	23.6%
	Milk collection, 1000 t	463.6	592.3	634.8	625.2	718.4	804.5	73.5%
	Percentage of collected milk, %	59.1%	72.9%	76.3%	75.2%	82.5%	83.0%	40.4%
	Raw milk trade balance, 1000 t	-9.3	–34.7	–65.5	–111.7	-211.5	-225.4	
	Milk processed, 1000 t	454.3	557.7	569.3	513.6	506.9	579.1	27.5%
	Ratio of processed to collected milk	98.0%	94.1%	89.7%	82.1%	70.6%	72.0%	-26.5%
Lithuania	Milk production, 1000 t	1,842	1,885	1,879	1,733	1,775	1,791	-2.7%
	Milk collection, 1000 t	1,138.6	1,296.8	1,382.1	1,278.3	1,359.9	1,435.6	26.1%
	Percentage of collected milk, %	61.8%	68.8%	73.6%	73.8%	76.6%	80.1%	29.6%
	Raw milk trade balance, 1000 t	0.0	113.2	190.0	181.6	301.8	268.4	
	Milk processed, 1000 t	1,138.6	1,410.1	1,572.1	1,459.8	1,661.7	1,704.0	49.7%
	Ratio of processed to collected milk	100.0%	108.7%	113.7%	114.2%	122.2%	118.7%	18.7%
Finland	Milk production, 1000 t	2,448.9	2,413.0	2,310.9	2,336.3	2,296.7	2,400.0	-2.0%
	Milk collection, 1000 t	2,372.7	2,347.6	2,253.9	2,288.6	2,254.0	2,357.2	-0.7%
	Percentage of collected milk, %	96.9%	97.3%	97.5%	98.0%	98.1%	98.2%	1.4%
	Raw milk trade balance, 1000 t	0.0	0.0	0.3	19.0	21.1	9.9	
	Milk processed, 1000 t	2,372.7	2,347.6	2,254.2	2,307.6	2,275.1	2,367.0	-0.2%
	Ratio of processed to collected milk	100.0%	100.0%	100.0%	100.8%	100.9%	100.4%	0.4%
Denmark	Milk production, 1000 t	4,568.4	4,627.2	4,656.0	4,910.0	4,915.7	5,162.0	13.0%
	Milk collection, 1000 t	4,433.8	4,492.1	4,585.6	4,817.5	4,915.7	5,112.6	15.3%
	Percentage of collected milk, %	97.1%	97.1%	98.5%	98.1%	100.0%	99.0%	2.0%
	Raw milk trade balance, 1000 t	–6.3	–32.5	-192.9	-187.0	-164.2	-183.7	
	Milk processed, 1000 t	4,427.5	4,459.6	4,392.7	4,630.5	4,751.5	4,928.9	11.3%
	Ratio of processed to collected milk	99.9%	99.3%	95.8%	96.1%	96.7%	96.4%	-3.5%
Germany	Milk production, 1000 t	28,244.7	27,995.0	28,656.3	29,593.9	30,672.2	32,381.1	14.6%
	Milk collection, 1000 t	27,112.8	26,821.2	27,465.6	28,659.1	29,701.8	31,375.3	15.7%
	Percentage of collected milk, %	96.0%	95.8%	95.8%	96.8%	96.8%	96.9%	0.9%
	Raw milk trade balance, 1000 t	–293.2	160.4	537.1	488.6	721.6	471.4	
	Milk processed, 1000 t	26,819.6	26,981.6	28,002.7	29,147.7	30,423.4	31,846.7	18.7%
	Ratio of processed to collected milk	98.9%	100.6%	102.0%	101.7%	102.4%	101.5%	2.6%
Netherlands	Milk production, 1000 t	10,904.7	10,994.7	11,620.5	11,940.5	11,881.0	12,660.4	16.1%
	Milk collection, 1000 t	10,531.8	10,625.6	10,936.0	11,626.1	11,675.6	12,468.4	18.4%
	Percentage of collected milk, %	96.6%	96.6%	94.1%	97.4%	98.3%	98.5%	2.0%
	Raw milk trade balance, 1000 t	–319.3	–357.8	–439.3	-373.6	-298.2	-311.6	
	Milk processed, 1000 t	10,212.6	10,267.7	10,496.7	11,252.5	11,377.4	12,156.8	19.0%
	Ratio of processed to collected milk	97.0%	96.6%	96.0%	96.8%	97.4%	97.5%	0.5%
Ireland	Milk production, 1000 t	5,307.1	5,271.8	5,113.7	5,349.7	5,399.3	5,821.3	9.7%
	Milk collection, 1000 t	5,267.8	5,224.5	5,089.9	5,327.0	5,379.7	5,818.7	10.5%
	Percentage of collected milk, %	99.3%	99.1%	99.5%	99.6%	99.6%	100.0%	0.7%
	Raw milk trade balance, 1000 t	96.8	140.0	54.5	48.3	96.3	385.5	
	Milk processed, 1000 t	5,364.6	5,364.5	5,144.4	5,375.4	5,476.0	6,204.3	15.7%
	Ratio of processed to collected milk	101.8%	102.7%	101.1%	100.9%	101.8%	106.6%	4.7%

[a] Raw milk trade balance is calculated as a difference between the import and export of products under CN code 04012099 milk and cream of a fat content by weight of > 3% but <= 6%, not concentrated nor containing added sugar or other sweetening matter (excl. In immediate packaging of <= 2 l).
[b] Milk processed is the sum of collected milk and raw milk trade balance.
Source: Eurostat (2015)

The first figure of the pair characterises the mechanisation and automation of the dairy processing industry, while the second figure indicates the average value of dairy processing industry products. It appears that labour productivity and the value of production per kg of processed milk in Estonian dairy processing industry exceed the figures of the Latvian and Lithuanian dairy sectors. However, production value and amount of milk processed has increased more in Lithuania, and Lithuanian dairy processing companies are catching up in the volume of milk processed per employee. There are three possible ways as to how Estonian and other Baltic dairy manufacturers could increase their labour productivity: 1) invest in the automation of processing plants (*e.g.*, from table 3 it appears that in Ireland, 1,041.1 tonnes of milk was processed per average employee in 2012, while in Estonia this figure was 4.5 times lower; at the same time, the value of production per kg of processed milk was lower in Ireland than in Estonia); 2) invest in product development and innovation to increase the production value per kg of milk processed (*e.g.* in Finland, the average turnover per kg of milk was 1.22 euros in 2013, while in Estonia the production value per kg of processed milk was 0.72 euros, *i.e.* 41.0% lower; at the same time, the volume of milk processed per employee was 2.0 times lower in Finland than in Ireland); 3) do both, 1) and 2). Germany and Netherlands represent the middle ground between options 1) and 2) with the volume of processed milk per employee and average value of products per kg of processed milk between the extremes of Ireland and Finland.

Table 3. Production value, number of employees, milk processed and labour productivity in the manufacture of dairy products in the period 2008–2013

Country	Trait	2008	2009	2010	2011	2012	2013
Estonia	Production value, million euros	320.7	268	309.9	345.8	328.2	362.1
	Number of employees	2,349	2,180	2,165	2,271	2,117	2,088
	Milk processed per employee, t	234.3	268.6	258.0	240.0	231.4	239.9
	Production value per employee, 1000 euros	136.5	122.9	143.1	152.3	155.0	173.4
	Production value per kg of processed milk, euros	0.58	0.46	0.55	0.63	0.67	0.72
Latvia	Production value, million euros	333.5	239.7	284.5	323.5	332.7	367.6
	Number of employees	3,718	3,165	3,024	3,011	3,163	3,120
	Milk processed per employee, t	153.1	150.6	169.8	165.4	160.2	167.9
	Production value per employee, 1000 euros	89.7	75.7	94.1	107.4	105.2	117.8
	Production value per kg of processed milk, euros	0.59	0.50	0.55	0.65	0.66	0.70
Lithuania	Production value, million euros	844	656.3	801.2	967.1	938.6	1,068.8
	Number of employees	8,625	8,095	7,627	7,597	7,721	7,607
	Milk processed per employee, t	182.3	177.0	191.4	202.9	215.2	216.8
	Production value per employee, 1000 euros	97.9	81.1	105.0	127.3	121.6	140.5
	Production value per kg of processed milk, euros	0.54	0.46	0.55	0.63	0.56	0.65
Finland	Turnover, million euros[a]	2327,9	2326,9	2277,7	2372,5	2489,5	2807,4
	Number of total employed staff[a]	4779	4612	4590	4690	4845	5254
	Milk processed per employee, t	471,7	499,1	502,7	485,3	469,6	438,9
	Turnover per employee, 1000 euros	487,1	504,5	496,2	505,9	513,8	534,3
	Turnover per kg of processed milk, euros	1,03	1,01	0,99	1,04	1,09	1,22
Germany	Production value, million euros	24,775.5	20,308.0	22,252.9	25,020.5	24,405.5	28,583.2
	Number of employees	38,080	35,809	36,450	39,737	41,062	42,068
	Milk processed per employee, t	735.4	805.0	799.7	755.2	740.9	734.6
	Production value per employee, 1000 euros	650.6	567.1	610.5	629.7	594.4	679.5
	Production value per kg of processed milk, euros	0.88	0.70	0.76	0.83	0.80	0.92
Netherlands	Production value, million euros	9,154.2	7,365	8,150.8	9,405.1	8,775.9	10,357.7
	Number of employees	11,801	12,134	11,470	12,078	12,234	12,695
	Milk processed per employee, t	889.5	909.0	981.0	928.1	930.0	939.3
	Production value per employee, 1000 euros	775.7	607.0	710.6	778.7	717.3	815.9
	Production value per kg of processed milk, euros	0.87	0.67	0.72	0.84	0.77	0.87
Ireland	Production value, million euros	3,290	2,750.3	3,441	3,828.3	3,671.2	3,638.9
	Number of employees	5,012	4,901	4,886	5,127	5,260	
	Milk processed per employee, t	1,026.4	1,003.0	1,100.2	1,095.6	1,041.1	
	Production value per employee, 1000 euros	656.4	561.2	704.3	746.7	697.9	
	Production value per kg of processed milk, euros	0.64	0.56	0.64	0.68	0.67	0.65

*Data for Denmark is missing; some of the data for Ireland in 2013 is missing
Source: Eurostat (2015), in the case of Finland, the data with superscript[a] are from Statistics Finland (2015)

One could ask that if labour productivity and the value of dairy products per kg of processed milk in Lithuania is lower than in Estonia, what makes the Lithuanian dairy processing industry more competitive than the Estonian and Latvian counterparts. Jansik *et al.* (2014) conclude that the total factor productivity has improved in the Lithuanian dairy processing sector at a quicker pace compared to Estonia and Latvia. In 2000–2011, the average annual total factor productivity growth in the Lithuanian dairy processing industry was 2.4%, while in Latvia it was 1.5% and in Estonia 0.3%. The other factors contributing to the greater competitiveness of the Lithuanian dairy processing industry are its more effective ability to find new export markets, scale effects in the processing industry and its larger domestic market, which gave Lithuanian dairies a better starting point for growth.

Milk demand

Food in general has many demand drivers, with the two main components of milk demand being population and consumption per capita. In 2003–2014, Estonia's population decreased by 4.3% to 1.32 million (Figure 11).

At the same time, the total consumption of fresh milk remained unchanged and per capita fresh milk consumption increased by 4.3%. In the 2003–2014 period, per capita fresh milk consumption was lowest (121.6 kg) in 2004, and highest in 2008 (140.8 kg). Income is one of the major drivers of consumption. Fresh milk is one of the products with low demand elasticity in relation to income because people tend to consume a relatively fixed amount of it. However, Figure 11 reveals that there is some correlation between fresh milk consumption changes and average net wage. Since 2004, economic growth accelerated and with it, net wages increased. The beginning of the recession in 2009 led to a decrease in net wages. At the same time, between 2009 and 2011, per capita fresh milk consumption decreased.

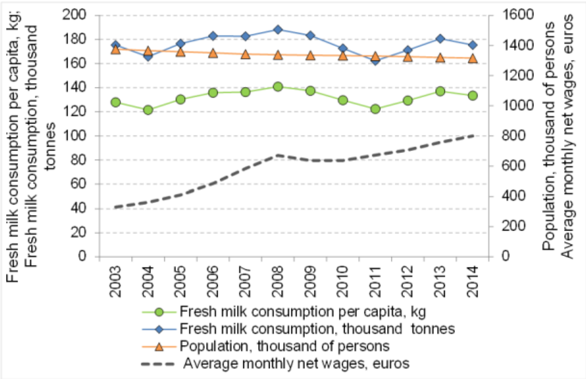

Figure 11. Fresh milk consumption *per capita,* fresh milk consumption, population and average net wage in Estonia in the period 2003–2014 Source: Statistics Estonia (2015)

When comparing Estonian per capita milk (milk products, excluding butter) consumption with the selected countries (Figure 12), one can notice the difference between Finland and the Netherlands and other selected countries. In Finland and the Netherlands, the average milk consumption per capita is larger and more stable than in other countries. In Lithuania, milk consumption per capita has been most volatile, but has an increasing trend. In Ireland, milk consumption was higher until 2003 and has declined in recent years. Estonia appears to be in the same group as Germany and Latvia in terms of milk consumption. In 2011, milk consumption varied from 214 kg/capita/year in Latvia to 395 kg/capita/year in Finland. Estonian per capita consumption was 239 kg.

In the period 2003–2104, there have been some changes in the structure of consumption of milk products in Estonia. The consumption of milk powder, skimmed milk and buttermilk decreased respectively from 3.9 to 0.6 kg/capita/year and 7.5 to 1.4 kg/capita/year. Average per capita butter consumption decreased from 4.9 to 2.1 kg. At the same time, the annual average per capita consumption of cheese and cottage cheese increased from 13.2 to 21.2 kg, and consumption of processed cheese increased from 0.8 to 5.6 kg (Statistics Estonia, 2015). These trends coincide with findings of Putnam (1989) from the end of 1980s in that, while there has been a reduction in demand for high fat fluid milk products, the consumption of relatively high-fat cheese products has been increasing.

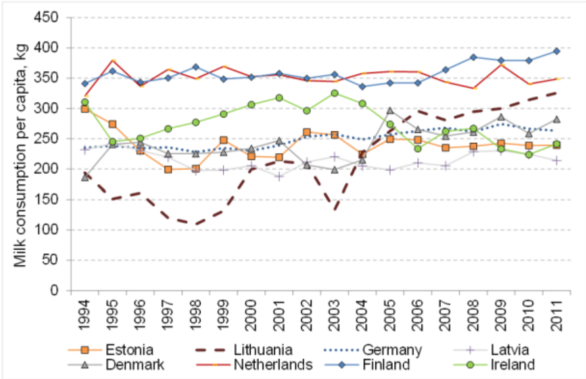

Figure 12. Milk consumption (excluding butter) per capita in the period 1994–2011 in selected countries, kg. Source: Faostat (2015)

From Figure 12 it can be seen that while per capita milk consumption has been more volatile in some countries, it is relatively stable in most countries. Therefore, potentially, when income increases, Estonian domestic consumers could demand larger quantities of milk and dairy products. However, considering the decreasing population and relatively stable per capita milk consumption (consumer preferences), a large increase in domestic demand is not likely and additionally produced milk should be marketed for export.

In recent years, there have also been changes in the purchasing channels of domestic consumers. In 2014, fresh milk was mainly (89% of consumers) purchased from stores (Figure 13), and less so from farmers. In the early 2000s, about 30% of consumers bought fresh milk from farmers. In recent years, that number has dropped significantly. Buying from farmers' markets and own production has also decreased over the years. The latter is explained by a significant drop in the number of dairy herds (Table 1). A new trend is that the number of people who do not consume fresh milk is increasing. In 2014, it amounted to 5%. Therefore, the main purchasing channel of milk in Estonia is retail stores. In the case of milk products, the general trends are similar to those of fresh milk. However, 70% of consumers bought milk products from stores as early as 2001. In 2014, stores were preferred by 95% of consumers, 2% of consumers bought milk products from farmers and 1% from markets. In recent years, 1–2% of consumers have revealed that they do not consume milk products. This trend is increasing, although the percentage of the population that does not consume fresh milk and milk products is still relatively low (TNS EMOR 2010, 2011, 2014).

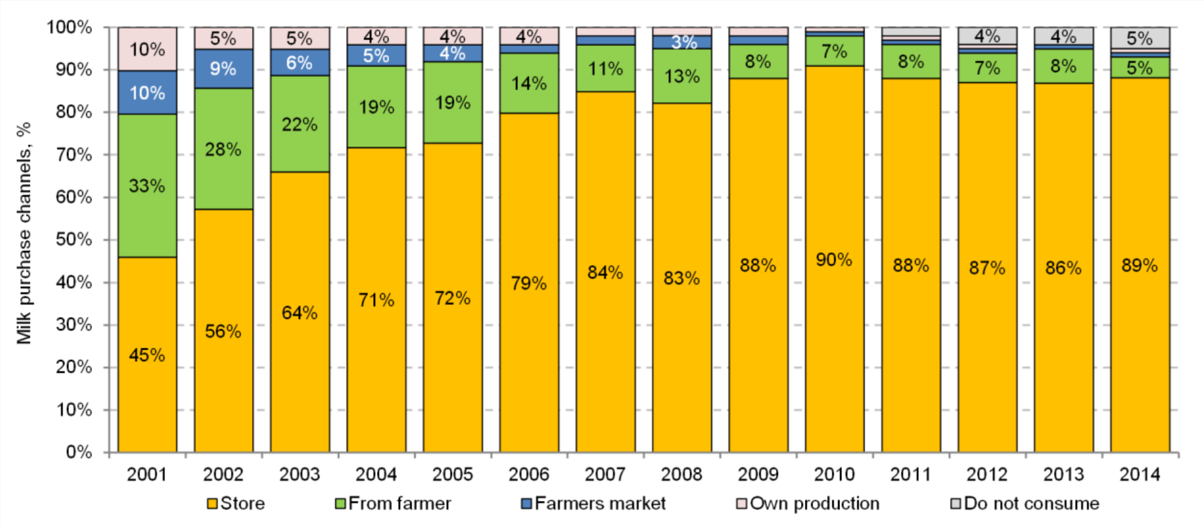

Figure 13. Milk purchasing channels in Estonia, %. Source: TNS EMOR (2010, 2011, 2014)

TNS EMOR (2010) has studied consumers' preferences with regard to the origin of milk products (Figure 14). The study included two milk products: yoghurt and cheese. Preferences regarding the origin of fresh milk were not studied, because fresh drinking milk is easily perished and is largely of Estonian origin. In the 1990s, 62% of consumers preferred yoghurt produced in Estonia. By 2010, the preference of Estonian yoghurt had increased to 81%, largely due to product development (Institute of Economic Research, 2013). Consumers' preference of cheese of Estonian origin had declined by 10 percentage points by 2010, compared to 1996. This could be associated with consumers' desire for a larger variety of cheeses when incomes and cheese consumption increases. However, as of 2010, 80% of Estonian consumers preferred yoghurt and cheese of Estonian origin.

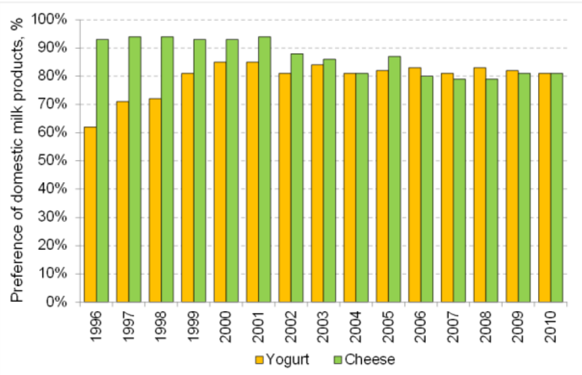

Figure 14. Preference of domestic milk products in the period 1996–2010, %. Source: TNS EMOR (2010)

Foreign trade and comparative advantage

Estonia was a net exporter of dairy products in the 1920s (Pihlamägi, 2004) and has retained this status since. However, there have been several changes in the structure of export products and markets. Therefore, one could claim that the ability to adapt to changing conditions in export markets is one of the crucial determinants of the competitiveness of the Estonian dairy sector. Dagenais and Muet (1992), and Vollrath (1991) provide analysis on the measures of comparative advantage. In the current paper, the most common indexes of revealed comparative advantage (RCA) are used. Fast economic growth in Estonia in the last two decades has caused significant structural changes. The competitiveness of agricultural commodities in the international market has changed and the structure of foreign trade has also changed. The integration of the Estonian economy into the world economy, accession to the EU and, more recently, the financial crisis have been the main drivers behind the dynamics of the Estonian dairy sector's competitiveness in export markets. In the study on the dairy export competitiveness of the EU countries, Bojnec and Fertő (2014) found that Estonia was competitive both on intra- and extra-EU markets between 2000 and 2011, along with Belgium, Cyprus, Denmark, France, Ireland, Latvia, Lithuania, the Netherlands and Portugal. In addition, Bojnec and Fertő (2014) concluded that the duration of the revealed competitive advantage (RCA>1) on the global dairy market was highest for Poland, Latvia, Lithuania and Estonia, implying long-term competitiveness on the global dairy market.

The dynamics of the export turnover of Estonian dairy products between 1994 and 2014 (Figure 15) coincides with the dynamics of producer prices of milk (Figures 2 and 4). The decline in the export turnover of dairy products in 1998–1999, in 2009 and in 2014 have coincided with the "Russian crisis", "Food crisis" and "Russian import ban". While the export turnover of dairy products was 47.6 million euros in 1994, it had increased by 304.8% to 192.8 million euros by 2014. At the same time, the producer prices of milk increased by 230.7% from 99.2 to 328.0 euros per tonne, milk production increased by 4.3% from 771.8 to 805.2 thousand tonnes and milk purchases by processing companies increased by 35.8% from 552.5 to 750.2 thousand tonnes. Therefore, the growth of export turnover exceeds the growth in production and processing volumes, and also the growth in the producer prices of milk.

Calculations of revealed comparative advantage are based on detailed trade data from the World Customs Organization's Harmonized System at 6-digit level (HS6) in 1996–2014. Furthermore, the detailed trade data is aggregated into three broader groups for distinguishing between various stages of the dairy chain. Bojnec and Fertő (2014) use a similar approach in aggregation. Using the Broad Economic Classification (BEC), the HS6 codes are divided to primary dairy products for household consumption (BEC code 112), processed dairy products mainly for industry (BEC code 121) and processed dairy and dairy products intended for final consumption in households (BEC code 122). Data is derived from the UN Comtrade database (UNSD, 2015). Similarly to Bojnec and Fertő (2014), a distinction between intra- and extra-EU trade is made. All trade with EU28 countries from 1996 to 2014 is considered here as intra-EU trade.

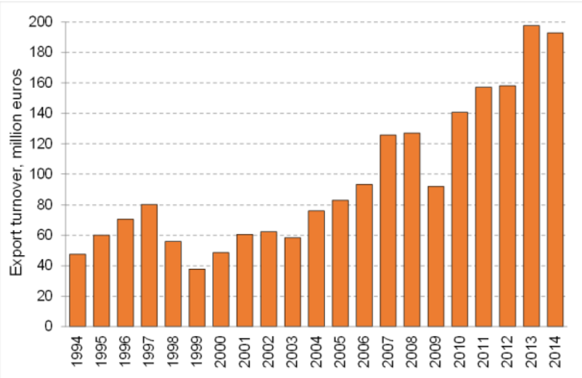

Figure 15. Export turnover (in nominal prices) of Estonian dairy products (CN codes 0401-0406) in the period 1994–2014, million euros. Source: Statistics Estonia (2015)

According to UN Comtrade data, the exports of dairy products in the mentioned categories accounted for 4.5% of Estonia's total exports in 1996 and it declined to 1.5% in 2014 (Figure 16). There has been a remark able shift from extra-EU trade to intra-EU trade. Intra-EU exports accounted for 36% in 1996, and 86% in 2014. The share of import of dairy products has been considerably low in total imports for Estonia, amounting to 1.2% in 1996 and 0.4% in 2014.

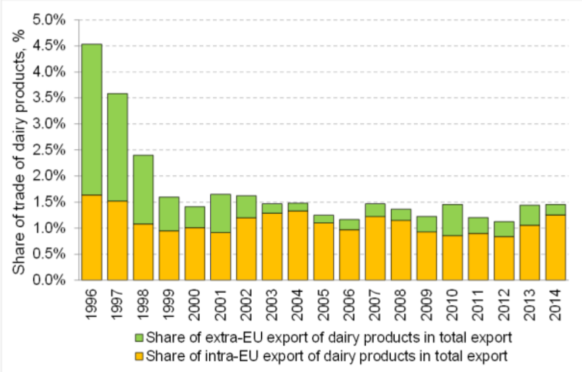

Figure 16. Share of intra-EU and extra-EU trade of dairy products in total exports of Estonia. Source: Comtrade database (UNSD 2015)

Prior to EU accession in 2004, most dairy product exports consisted of processed products. Processed products for households and industry accounted for 85% in 1996, and the share of primary products has risen since EU accession, comprising almost half of exports in 2014 (Figure 17).

However, it should be noted that the description of BEC code 112 (primary products for households) is somewhat misleading in the case of Baltic countries. Most of the value under this code is accounted for by raw milk that is exported to the dairy processing industry of neighbouring countries. The average annual growth in the share of the exports of primary dairy products, which mostly comprises raw milk for processing, was 6.5% between 1996 and 2014. The share of processed products for industry has declined and the share of processed products for households has remained at the same level.

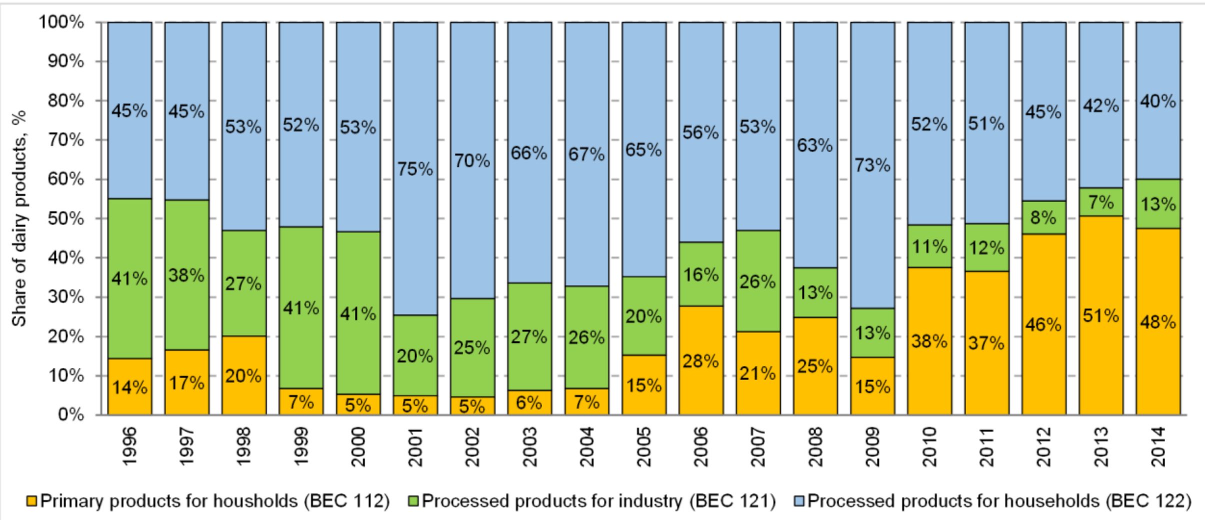

Figure 17. Share of dairy products of the various stages of the dairy chain in exports. Source: Comtrade database (UNSD 2015)

The development of the structure of the export of dairy products could be divided into three sub-periods. From 1994 until the period preceding EU accession (beginning of 2000s), the main groups of export dairy products were concentrated milk and cream, *i.e.* skim milk powder and whole milk powder (Combined Nomenclature (CN) code 0402) and butter (0405) (Figure 18). From 2001 onwards, the share of cheese (0406) in export turnover started to increase until 2009, when it reached to almost 50%. After the crisis in 2009, the share of milk and cream (0401) started to increase, and the share of other product groups began to decline. This is related to the phenomenon known as "raw milk trade", which gained momentum after the 2004 EU enlargement (Jansik *et al*., 2014). In Estonia's case, raw milk was exported to Lithuanian and Latvian markets. This also explains the growth in primary products for households (BEC112) in Figure 17. While in customs union, some amount of raw milk trade is rational (Table 2), the high value share of raw milk in the dairy exports in Estonia and Latvia reflects the lack of processing volume and competitiveness of the dairy processing industry in these countries (Jansik *et al*., 2014).

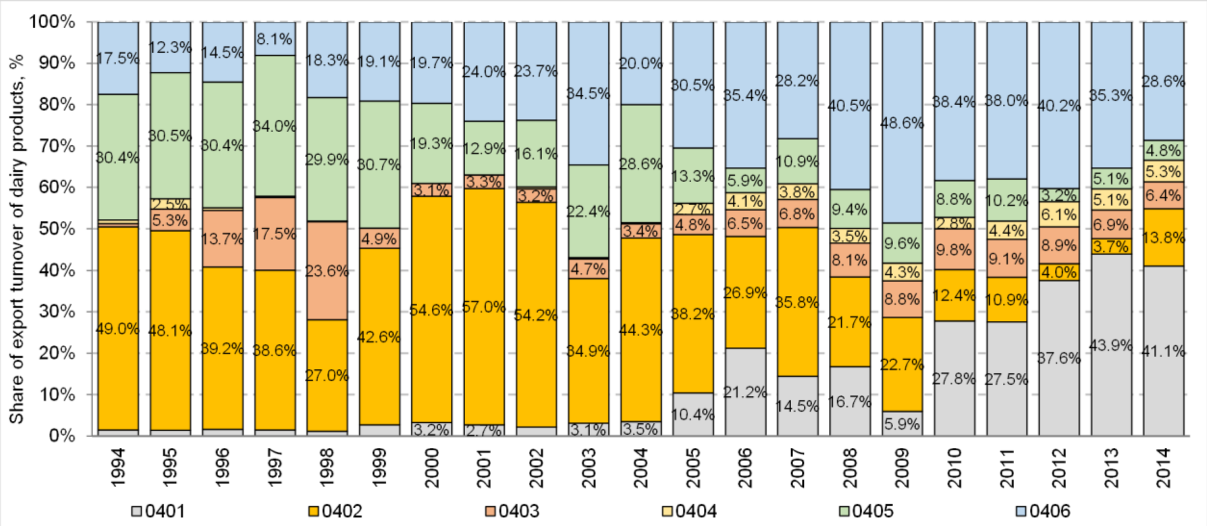

Figure 18. Structure of the export turnover of Estonian dairy products (CN codes 0401-0406) in the period 1994–2014. Source: Statistics Estonia (2015) (0401 – milk and cream, not concentrated; 0402 – milk and cream, concentrated; 0403 – buttermilk, curdled milk and cream, yogurt, kephir and other fermented or acidified milk and cream; 0404 – whey; 0405 – butter and other fats and oils derived from milk; dairy spreads; 0406 – cheese and curd)

Results from the calculations of the Balassa index of revealed comparative advantage (RCA) indicate that Estonia has a comparative advantage in the export flows of all three categories of dairy products (Figure 19).

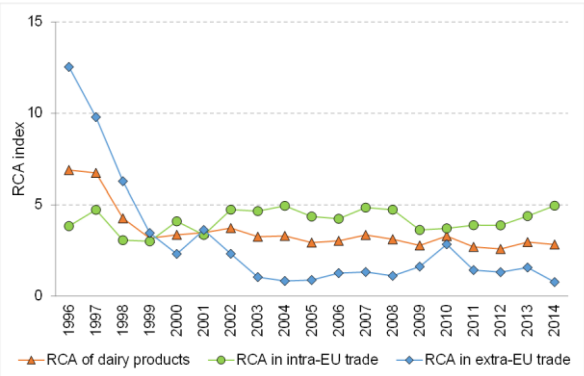

Figure 19. Dynamics of the revealed comparative advantage (RCA) index of dairy products. Source: Authors' calculations based on Comtrade database (UNSD 2015)

The RCA index of all dairy products was >1 throughout the entire period of 1996–2014. In Figure 19, a distinction between intra- and extra-EU trade is made. One can see that the RCA index for extra-EU trade was very large prior to 1999 and has declined considerably since. In 1999–2010, the RCA index remained >1 and was fluctuating between the values of 2.7 and 3.7, indicating a stable revealed comparative advantage. Though the value of the index has not changed significantly, there are changes in the structure of revealed comparative advantage. The RCA of intra-EU trade has been considerably higher than extra-EU trade since 2001. Following accession to the EU in 2004 and in the following year, the RCA index for extra-EU trade even indicated a slight disadvantage in trade. The RCA index for extra-EU trade declined below one again in 2014 due to the disappearance of the Russian export market following the import ban.

From Figure 20, it appears that there have been changes in the main export destinations in the period 1994–2014, which partly explain the changes in the revealed competitive advantage in intra- and extra-EU trade. In 1994–1998, the share of dairy products exported to Russia remained above 33% on average. The second largest export destination was the Netherlands. After the crisis in 1999, the share of Russian Federation in dairy export destinations declined and almost diminished by 2003 due to the double import tariffs policy employed by Russia. At the same time, the share of the Netherlands increased to almost 50% in 2003. Since 1999, the share of other EU15 countries also started to increase. After the EU accession in

2004, the structure of the main export destinations again changed. The Russian market opened again for Estonian dairy products and the share of Russia in export destinations began to increase. Since 2014, the share of the closest neighbouring countries of Latvia, Lithuania and Finland also started to increase. By 2014, the number of export destinations had significantly declined. The four major export markets (Lithuania, Latvia, Finland and Russia) accounted for 76.6% of the total export turnover of dairy products.

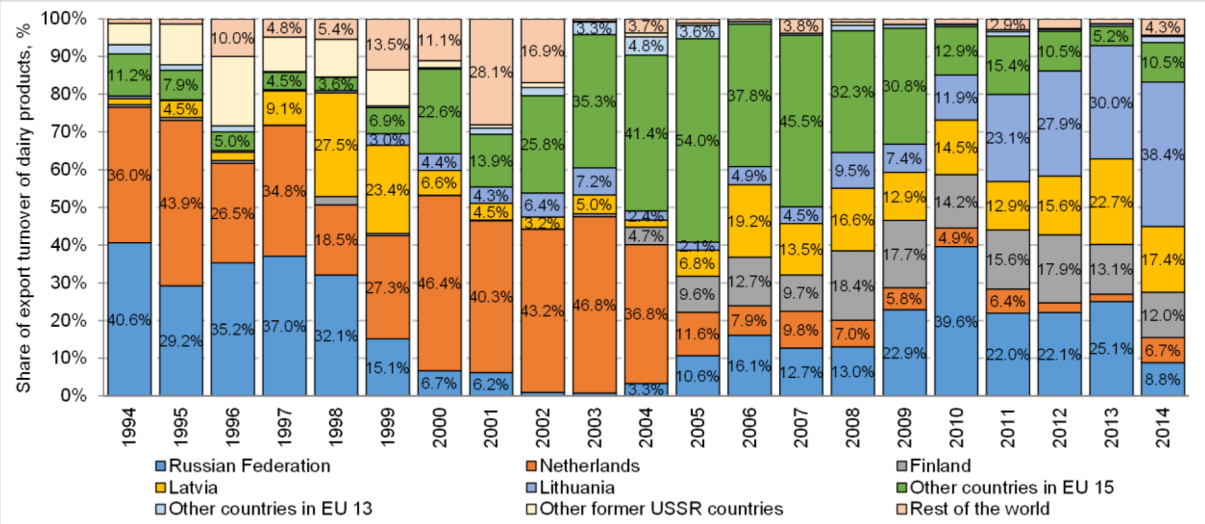

Figure 20. Structure of the export turnover of Estonian dairy products by destination in the period 1994–2014. Source: Statistics Estonia (2015)

There have also been changes in the structure of revealed comparative advantage in terms of the products in various stages of the dairy chain (Figure 21). The RCA index of processed products for households (BEC 122) showed stable decline in RCA from 4.3 in 1996 to 1.7 in 2014, remaining >1 and indicating comparative advantage. This advantage is based on the relatively successful exports to both EU and non-EU countries. There has been a considerable decline in the RCA index for processed dairy products mainly for industry use (BEC 121). The values of the Balassa index still indicate comparative advantage being slightly more successful in the direction of EU countries. Contrary to processed products, there has been an increase in the RCA index of primary products (BEC 112) for both for household and industry use. The RCA index for primary products declined before 1999 and began to rise again, reaching 8.4 in 2014 (significantly affected by raw milk export).

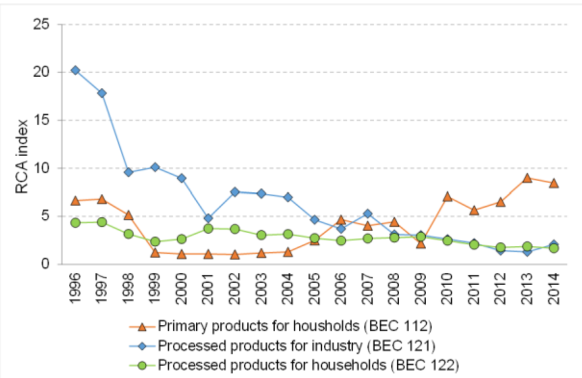

Figure 21. Dynamics of the revealed comparative advantage (RCA) index of dairy products of the various stages of the dairy chain. Source: Authors' calculations based on Comtrade database (UNSD 2015)

The analysis of revealed comparative advantage shows that there are three stages to be considered in the period between 1996 and 2014. First, the period before 2004 when there is a decline in the overall RCA of dairy products prior to 1999 and the relative successfulness of processed products for industry use. Second, the period from 2004 to 2009, where all three product categories show the same level of revealed comparative advantage. The third period is that after 2009, when the exports of primary products, including raw milk, became more advantageous compared to other products.

Discussion and conclusions

In the last 20 years, the Estonian dairy sector has remained export orientated and competitive in export markets. The strength of Estonian dairy farms lies in the high milk yields and relatively large scale farms, which reduce the transport costs for dairies. At the same time, there are aspects in dairy farms that need improvement. According to Kimura and Sauer (2015), the total factor productivity growth remains close to zero, indicating a problem with a rapid increase in input use and a decline in other animal output (live animals and beef), besides milk. The latter is affected by the reducing life span of dairy cows, which also hampers selection of heifers for the replacement of dairy cows. In the long term, this trend has negative effects on the competitiveness of Estonian dairy farms. Therefore, the challenge of dairy farms lies in how to more effectively exploit the investments made and, while maintaining the achieved high yield level, reduce input use and stop the negative trend of the decreasing average life span of dairy cows.

Rapidly increasing milk yields and an increase in the percentage of Estonian Holstein cows has reduced average milk fat content and slightly increased milk protein content. In the Netherlands, Denmark and Finland, both average milk fat and protein content exceed the Estonian figures. Therefore, the dairy processing industry in these countries uses less raw milk for the same amount of manufactured dairy products compared to Estonian dairies. In 2013, the average milk protein content in Estonia exceeded the Lithuanian figure by 4.3%. Lithuania is specialised in producing and exporting of cheese. The higher milk protein content in Estonian milk could be one reason why Lithuanian dairies import raw milk from Estonian farms. The other advantages of Estonian milk in the Baltic raw milk market lie in concentrated dairy farms (which lower transport costs) and the lower seasonality of production (which enables more efficient utilisation of processing capacity).

While milk production and collection in Estonia have increased markedly, the amount of milk processed in Estonian dairies to dairy products has increased to a lesser extent. In 2014, 25.2% of collected milk was exported as raw milk to Latvia and Lithuania. This reflects the more effective competitiveness of the Lithuanian dairy processing industry, which processes more milk than is produced in Lithuania. One of the contributory factors to the success of the Lithuanian dairy processing industry is its good ability to find markets for its products as well as its higher level of marketing innovation compared to the processing companies in other Baltic countries (Jansik *et al*., 2014; Melece, Krievina, 2015). The labour productivity in the Estonian and Baltic dairy processing industry is significantly lower compared to Scandinavian and Central European countries. Also, the value of dairy products per kg of processed milk is lower compared to Finland and Germany. In order to increase competitiveness, the Estonian dairy processing industry needs to increase the amount processed in Estonia, labour productivity and value added per kg of processed milk, and it needs to be effective in finding export markets for its products.

Bojnec and Fertő (2014) conclude that most EU countries should specialise in their dairy exports, since they are not competitive in all market segments. In recent years, the Estonian dairy sector has specialised in cheese and raw milk exports, mainly to neighbouring countries: Lithuania, Latvia, Finland and Russia. While this kind of specialisation seems rational for a small country, concentrating on specific products and markets may cause major drawbacks. The import ban imposed by Russia in 2014, for example, has resulted in a deep crisis in the Estonian dairy sector. In 2013, dairy exports to Russia comprised 25.1% of total dairy exports, and the share of the neighbouring countries of Latvia, Lithuania and Finland were 22.7%, 30.0% and 13.1%, respectively. Therefore, 90.9% of all dairy exports were targeted to neighbouring markets, which were also exporting significant amounts of dairy products to Russia. In addition, milk and cream (CN code 0401, mainly raw milk) comprised 43.9%, and cheese and curd (0406) 31.3% of all dairy exports. These two product groups comprised 75.2% of all dairy exports. Therefore, one could argue that Estonian dairy exports are already relatively specialised.

Low world market prices have had a role in the majority of crises in the Estonian dairy sector. However, in 2009, the crisis coincided with the economic recession, due to which farm payments were also reduced in Estonia. Farm payments also declined in 2014, amplifying the negative effects of low prices. However, abolition of the EU milk quotas in 2015 and an increase in EU milk production changes the policy and market context in the EU and world dairy markets. The EU and Estonian milk producers are not isolated from world markets and milk prices in the EU converge with the world market prices, implying increasing pressure on cost reduction and, potentially, increased price volatility. Appropriate measures for smoothing the effects of price volatility on farm incomes are yet to be determined.

Crises represent a turning point for trends in Estonian dairy sector’s development. After each crisis, there have been some changes in the prevalent trends: in the beginning of the 1990s, the dairy sector adapted to changing institutions, agricultural policy and markets. After 1999, dairy exports were reorientated from Russia's markets to EU countries. EU accession once again changed institutional and policy context and brought along reorientation to export markets. The 2009 dairy crisis resulted in raw milk exports to other Baltic countries. The crisis that started in the second half of 2014 has resulted in a significant drop of number of dairy cows and the disappearance of Russian market once again. Therefore, the competitiveness and resilience of the Estonian dairy sector lies in its ability to adapt to changing situations. For dairy farms, it implies a greater ability to alter average production costs, and production volume, according to market situation.

The dairy industry could be considered the weaker link in the farming and industry links of the Estonian dairy chain. Therefore, the future competitiveness of the Estonian dairy sector is largely related to the development of the dairy processing industry. The potential exists (raw milk that is exported) to increase the volume of milk processed in Estonia. However, this would require the suppliers of exported raw milk (dairy farmers) to be willing to deliver this milk to local processors. One of the solutions here could lie in establishing a dairy processing company that is owned by dairy farmers. This could be established as a new company, but could also be founded on the basis of some existing dairy manufacturers. Still, considering the crisis in the dairy sector in 2015, it is questionable whether dairy farmers have the necessary capital for this investment. Therefore, it is necessary to develop the existing dairy manufacturers. In doing so, it should be considered that additionally produced dairy products should be exported. In order to reduce the risks of concentrating on neighbouring markets, new markets should be found among the countries that are not closely linked to the Russian market. It is likely that the product portfolio should be developed in accordance with the demands of these export markets. In order to increase the productivity of the Estonian dairy manufacturing industry, either the volume of milk processed per employee or the product value per kg of processed milk, or indeed both, should be increased. In the short term, the first of these options seems more plausible. However, Estonia is a small country with a small milk production volume in global terms. Therefore, it is questionable whether the long term success of the Estonian dairy industry can lie in very large scale cost efficient processing. This implies a need for intensified research, development and innovation activities in the dairy industry, which require significant investments in human and physical capital, as well as time. Consequently, research, development and innovation should be facilitated in associated public and private organisations. Ultimately, it should not be forgotten that if a product is produced efficiently, and even if it contains potentially high value added, it has to be delivered to end consumers. That requires good marketing capability in the dairy sector together with efforts from government that can facilitate the access of dairy manufacturers to new extra-EU markets.

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AHVENAMAA AEDADES

Mänd kasvab välja sammeldund graniidist.
Kus veidi mulda, seal on tasahilju
maa põlluks muutund karmist kiviriigist.
Nüüd kannab õunapuid, täis sulneid vilju.

Akadeemilise Põllumajanduse Seltsi tänavune reis viis suve alguses (28.06–01.07) huvilisi tutvuma Ahvenamaa õuna- ja marjakasvatusega. Koos teadlastega oli ka praktikuid ja huviaednikke. Sõidu korraldamise põhiraskust kandsid Heldur Peterson ja Alo Tänavots. Tänu neile vaeva eest!

Ringkäiku alustasime teadlaste juures. Jomalas asuvas katseaias kohtasime Eestis aretatud õuna-, pirni- ja vaarikasorte. Vaarikad kasvasid kütteta kasvuhoones. Sealses pehmes kliimas võib meie sortidel edu olla. Aimus teadlaste ja hiljem külastatud äriaednike hea koostöö.

Suured kaasaegsed õunaaiad avaldasid muljet. Külmas säilitatud frigo-istikutega tänavu rajatud aiaosad olid äsja õide puhkenud. Istikud ostetakse Hollandist. Nii olevat odavam. Üllatas ennakvõrsetest kujunenud külgokste õitsemine üheaastase poogendiga istikutel. Mitmed kaasaegsed õunasordid annavad oma esimesed saagid pikkade aastakasvude külgpungadest, nagu see on omane vaarikatele. Siin õitsesid ka ennakvõrsetest arenenud külgoksad. Selline õiepungade teke võimaldaks juba istikult vilju saada. Paraku ei lasta sel õierikkusel istutusaastal viljadeks areneda. Esimesel kasvuaastal on eesmärgiks puu juurdumine ning võra kujunemine.

Külastasime Tjudös asuvaid aedu. Saare suurima õunaistandusega Grannas Äppel (Granna Frukt), kus istandikke on üle 30 hektari, tutvustas meid Jan Mattsson. Aedades kasutati puude ruumilist spaleertoestust. Arenevad külgvõrsed suunati ja kinnitati reakohast paarikümne sentimeetri kaugusele pingutatud traatidele. Kujundatakse 2–3 rindega võra. Saime maitsta väikestesse pudelitesse villitud omatoodetud õunamahla. Jon Lindemani istandikes olid puud kõrgemad, sest õunu koristatakse traktoriplatvormil olles.

Gotbys asuvas Harry Söderbergi marjakasvatustalus nägime sõstra- ja maasikaistandikke. Maasikaid toodeti nii avamaal kui kasvuhoones.


Üldpilt osalejatest (foto: Alo Tänavots)


Seltsi president Marko Kass ja aupresident Heldur Peterson (foto: Alo Tänavots)


Mänd kasvab välja sammeldund graniidist (foto: Alo Tänavots)


Harri Söderbergi juures (foto: Alo Tänavots)

Istutatud harunenud õitsev istik oli poogendist arenenud ühe suvega (foto: Jaan Kivistik)

Külgoksad kinnitati puude reast veidi kaugemale pingutatud traatidele (foto: Jaan Kivistik)

Alumise rinde okstel oli juba vilju, ülalpool kujuneb võrsetest teine rinne (foto: Jaan Kivistik)

Teisel päeval tutvusime saareriigi loodusega ja valitsemisega. Ahvenamaa parlamendihoones rääkis kohalik eestlanna Marina Eriksson meile sealse riikluse ajaloost ning tänapäevast. Sel rootsikeelsel Soome riigi demilitariseeritud osal on suur autonoomia. Ahvenamaa kodanikel pole väeteenistuse kohustust. Mittekodanikud ei saa osta maavaldusi. Saarele ümberasujad võivad taotleda Ahvenamaa kodakondsust viie aasta pärast, kui neil on Soome kodakondsus ja rootsi keele oskus. Kodanik, kes on elanud mujal kauem kui viis aastat, kaotab kodakondsuse. 27 tuhande elanikuga saareriik on Põhjamaade Nõukogu liige. Halduskeskuses Mariehamnis elab ligi 11 tuhat inimest.

Tagasiteele asusime veidi enne südaööd ehavalguses. Ilus ja õpetlik reis oli!

Jaan Kivistik

APSi PRESIDENDI TERVITUS JUUBELI PUHUL

Lugupeetud seltsikaaslane,

Lubage mul Teid õnnitleda seltsi 95. aastapäeva puhul. Just täna, 95 aastat tagasi, 3. detsembril 1920 registreeriti Akadeemiline Põllumajanduse Seltsi (toona Akadeemiline Põllumajanduslik Selts) juriidilise organisatsioonina Tartu Ülikooli valitsuse poolt. Aasta varem avatud emakeelse ülikooli põllumajandusteaduskonna üliõpilased lõid organisatsiooni, mis kasvas üsna pea suureks nii oma liikmeskonnalt kui tegevustelt. Seltsiga liitusid ka õppejõud, kes oma eeskuju ja teadmistega innustasid üliõpilasi nii õppetöös kui seltsi ettevõtmistes. Toona seati seltsi eesmärgiks liikmete mitmekülgne arendamine ja kujundamine edukaks tulevaseks kutsetööks ning kodumaa põllumajanduse edendamiseks.

Kuigi täna on kutsetööks ettevalmistamine jäänud maaülikooli ja mitmete ametikoolide õlule, täidab meie selts endiselt oma eesmärke: korraldame teaduslikke konverentse ja ettekandekoosolekuid, ning anname välja ainsat põllumajandusteemalist teadusajakirja Agraarteadus. Aitäh teile kõigile, et olete panustanud eelpool mainitud tegevustesse!

Mul on väga hea meel, et oleme hoidnud oma traditsioone, sest see ongi meie tugevus. Aitäh teile, austatud seltsiliikmed, et korraldate jätkuvalt seltsi õppereise ja ajaloopäevi. Need on minu ühed lemmikud! Ühtlasi suured tänud seltsikaaslastele, kes veavad oskussõnade töörühma.

Siirast rõõmu tunnen ka uute traditsioonide üle nagu seda on Eesti Vabariigi sünnipäeva tähistamine kontsert-aktusega K.E. von Baeri majas. Sest selts, mis on ellu kutsutud Tartu rahuga samal aastal, teab ja oskab hoida ka oma kodumaad!

Tänasel tähtpäeval tahan teiega jagada ka ühte oma unistust. Nimelt aasta tagasi sai maha hõigatud idee koostada seltsi 95. juubeliks raamat, mis vaataks tagasi seltsi tegusatele aastatele nii sõnas kui pildis. Sestap loodan teie kõigi, armsad seltsikaaslased, abile ja toele, et saaksime juba eeloleval varakevadel käes hoida seltsi juubelikogumikku.

Austatud seltsikaaslased, soovin teile veel korra palju õnne seltsi 95. aastapäeva puhul ning edu ja tervist teile kõigile!

Lugupidamisega,
Marko Kass, seltsi president

ENN LEEDU 70 – MÕNDA TEMA AKADEEMILISEST KARJÄÄRIST

Eesti Maaülikooli Mullateaduse ja agrokeemia osakonna dotsendi Enn Leedu (sünd. 15. aprillil 1945. a) praktiku-teadlase-õppejõu karjäär on ligikaudu võrdsetes osades kulgenud Eesti Maaülikoolis ja Eesti Põllumajandusprojektis. Nüüd juba üle 45 aasta kestnud tegevusse agronoomi-mullateadlase-õppejõuna on Enn Leedu tulnud läbi Olustvere Sovhoostehnikumi (lõpetas 1965), EPA Agronoomia teaduskonna (lõpetas 1970) ja EPA statsionaarse (mullateaduse eriala) aspirantuuri (1970–1973).

Magistri teaduskraad mullateaduse alal omistati talle 1997. a uurimuse eest, mis käsitles põlevkivikarjääride puistangute ja nende põllumaaks rekultiveerimisel kasutatava huumusmulla agrofüüsikalisi ja agrokeemilisi omadusi. Põllumajandusteaduste doktoriks taimekasvatuse erialal (1998. a) sai ta väitekirja *Põlevkivi kaevandamisega Eesti põllumajandusele tekitavate kahjude leevendamise võimalused* kaitsmise tulemusena. Selle EPMÜ doktorinõukogu otsuse järel jätkas Enn Leedu oma tööd juba dotsendi ametikohal.

Eesti Põllumajandusprojektis töötamise ajal aastatel 1976–1994 oli tema põhitegevuseks arendustegevus ja rakenduslikud uurimused mullateaduse (sh agrokeemia), maaviljeluse ja taimekasvatuse alal. Põhiosas hõlmas see Ida-Virumaa ammendatud põlevkivikarjääride pinnaste põllumajandusliku rekultiveerimise viiside väljatöötamist ja nende praktikasse rakendamist. Põllumajandusliku rekultiveerimisvõimaluste uurimisega kaasnesid mahukad põldkatsed erinevate kultuuridega. Samas piirkonnas selgitati veel ka allmaakaevanduste langatumise tõttu toimunud muldkatte degradeerumise määra ja selle mõju põllukultuuride saagikusele. Kontrollimaks taolisi ja teisi maade kasutamisega seotud väärnähtusi olid talle aastateks 1989–94 antud maade kasutamise ja kaitse riikliku inspektori volitused.

Alates 1992. a lisandus E. Leedu mullateaduse alasele arendustegevusele ja uurimistöödele tänaseni kestev õppetöö EMÜ Mullateaduse ja agrokeemia osakonnas. E. Leedu õppejõuks kutsumisel oli oluline ka see, et ta töötas kateedri laborandina juba aastatel 1968–70 olles siis üliõpilane, assistendina aastatel 1973–75 s.o vahetult peale aspirantuuri ja koges ühe vegetatsiooniperioodi jooksul peaagronoomi tööd Viljandi rajooni "Linda" kolhoosis. Valdavalt on dotsent Leedu õpetanud mullateaduse teoreetilisi aluseid ning Eesti muldade taksonoomiat, omadusi, kasutamist ja kaitset väga mitmesugustele erialadele spetsialiseerunud EMÜ üliõpilastele. Praktiliste laboratoorsete tööde käigus on ta juhendanud mulla analüüside tegemist ning mulla morfoloogial ja geneesil põhineva Eesti muldade klassifikatsiooni omandamist. Üliõpilaste auditoorne õppetöö on üldreeglina päädinud välipraktikaga, kus õpitakse tundma muldkatte koosseisu ja omaduste iseärasusi seoses teatud konkreetsete Eestimaa mullastikulis-ökoloogiliste tingimustega. Kaasautorina on E. Leedu teinud ka oma panuse nii kõrgkooli õpiku *Mullateadus* (ilmus 2012), kui ka praktiliste tööde juhendi *Muldade väliuurimine* (ilmus 2013) väljaandmisse.

Meie ülikoolile tavakohaselt on ka E. Leedu rööbiti õppetööga osalenud teaduslikus uurimistöös. Esimeseks tema uurimisteemaks oli mineraalväetiste kasutamine. Selle kohta sai prof P. Kuldkepi juhendamisel koostatud diplomitöö (1970. a), kus uurimise all olid Lõuna-Eesti erosiooniala mullad. Hiljem on E. Leedu selle probleemi juurde tagasi tulnud uurides väetamise mõju nii saagile ja saagi kvaliteedile ning toiteelementide sisaldusele ja bilansile, kui ka mulla taimekasvatuslikele omadustele pikaajalises külvikorra katses. Käesoleval ajal kestev prof P. Kuldkepi poolt 1989. a rajatud IUSS mullaviljakuse uurimisgrupi Euroopa võrgustikku kuuluv pikaajaline põldkatse (IOSDV/ILTE) on olnud heaks polügooniks ka E. Leedule nii orgaaniliste, mineraalsete kui ka kompleksväetiste uurimisel koostöös selle katsega seotud kollektiiviga nii EMÜ mullateaduse ja agrokeemia osakonnast, kui ka rahvusvahelises koostöös (ühisprojektid Berliini Humboldt'i Ülikooliga, Giesseni Justus von Liebigi Ülikooliga). Eespoolnimetatud pikaajalise külvikorra katse korraldamise vastutavaks täitjaks on tulnud olla aastatel 2000–2004 ka E. Leedul. Selle katse baasil sai alguse ka põlevkivi utmise jäägi poolkoksi ja sellest valmistatud kompostide (rekultiveerimisaine) kasutamisvõimaluste selgitamine taimekasvatuses. E. Leedu kogemused põllumajandusliku rekultiveerimise, põllumaadel toimunud kaevanduste langatuste ja põlevkivi poolkoksist valmistatud rekultiveerimisaine kohta on avaldatud eraldi peatükkidena kogumikus *Maavarade kaevandamine ja puistangute rekultiveerimine Eestis* (2010). E. Leedu on üheks Eesti parimaks asjatundjaks huumusmulla säilitamise ja põllumajandusliku rekultiveerimise alal.

E. Leedu aspirantuuriaegseks teemaks oli hoopiski kahekihilisel lõimisel (katte saviliiv liivsavimoreenil) kujunenud kahkjate muldade mineraloogia uurimine (juhendaja A. Oja), mille kohta on ilmunud ka mitu artiklit. Mõnes artiklis ja vastavasisulises juhendis on E. Leedu (koostöös E. Asi ja R. Kõlli'ga) argumenteerinud põllumaade metsastamise teemadel.

E. Leedu mitmekülgses arendustegevuses saadud teadmised on tulnud kasuks Taani-Eesti ühisprojekti *Väetiste kasutamise normatiivide täpsustamine ja sõnniku standardite väljatöötamine* Eestipoolse koordineerijana (2000–2002) ja selle raames koostöös Jäneda Õppe-Nõuandekeskusega juhendi *Põllukultuuride väetamine* väljaandmisel (2002).

E. Leedu teadlaseks-õppejõuks kujunemise loost selgub, et tema peamisteks mentoriteks ja kaasautoriteks on olnud E. Kitse, P. Kuldkepp, L. Reintam ja

A. Oja. Ilmunud publikatsioonide loetelu näitab, et tema hinnatuimateks koostööpartneriteks-kaasautoriteks on olnud ka L. Murdam, E. Kaar, A. Toomsoo, T. Teesalu, L. Lainoja, H. Raave, T. Tõrra ja veel mõned teised.

Oma kompetentsusest lähtuvalt on ta olnud kursuse juhendaja ning on kuulunud Üleliidulise Rekultiveerimise Nõukogu ja Eesti Paepargi Nõukogu koosseisu. Rahva teadlikkuse tõstmisel muldadega seotu kohta on olulised olnud avatud ülikooli kursuse *Muld ja toiteained* läbiviimine koos prof P. Kuldkepiga, õpilaste koolitused Toomal teemal *Muld ja turvas* koos dots M. Shanskiy'ga, Järvselja õpperaja muldadesse puutuva osa koostamine ja EMÜ Mullamuuseumi Eerikalt Tähtverre kolimine ja töökorda seadmine. Erialast lähtuvalt kuulub dots Leedu Eesti Mullateadlaste Seltsi, Akadeemilisse Põllumajandusseltsi ja Euroopa Mullakaitse Seltsi. Tema hobideks on tehnika, aiandus ja fotograafia. Nooremas eas tegeles ta edukalt laskespordiga, praegu aga hoiab end vormis sulgpalli mängimisega ning lastelastega matkates. Tema perekonnas on üles kasvanud tütar ja poeg, ning lapselapsi on tal kokku kolm.

Raimo Kõlli

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MMI – metsandus- ja maaehitusinstituut
Institute of Forestry and Rural Engineering
PKI – põllumajandus- ja keskkonnainstituut
Institute of Agricultural and Environmental Sciences
TI – tehnikainstituut / Institute of Technology
VLI – veterinaarmeditsiini ja loomakasvatuse instituut
Institute of Veterinary Medicine and Animal Sciences