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EARTHWORM (OLIGOCHAETA, LUMBRICIDAE) COMMUNITIES IN COMMON SOIL TYPES UNDER INTENSIVE AGRICULTURAL PRACTICE IN LATVIA

Jānis Ventiņš

Faculty of Geography and Earth Sciences, University of Latvia, Raiņa bulv. 19, Rīga, LV-1586, LATVIA
E-mail: ventins@lu.lv

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Studies of earthworm populations in the framework of the State Agricultural Land Monitoring Programme were performed during 1992–1998 at six sites representing the common soil types of Latvia. The earthworm communities were examined as indicators of soil conditions in relation to soil type, terrain, agricultural practice and meteorological factors. In total six earthworm species were found. Only two species, Aporrectodea caliginosa *and* Lumbricus rubellus*, were present in all plots. The highest density of earthworms was observed in loamy soils on lower terrains. The lowest density was observed on sandy soils on high terrain position. In plots with intensive agricultural practice,* Aporrectodea caliginosa *showed the highest relative abundance reaching close to 100%, but in pastures this species was accompanied with 2–3 subdominant species. The main factors affecting earthworm density were meteorological conditions. In permanent pasture the seasonal variability of earthworm number was lower than in plots with intensive soil tillage, where earthworm density was lower. Under favourable meteorological conditions in loamy soils, a negative impact of soil management was not observed, whereas in sandy loam soils intensive tillage had a much more negative effect on worms. In pasture soils earthworms reached high density even in sandy soils.*

Key words: *earthworm community, soil properties, agroecosystems, soil treatment.*

INTRODUCTION

Earthworms play an important role in soil formation and promotion of soil fertility. Presence of a well-developed earthworm community in the soil of an agricultural field should be regarded as an indicator of good soil conditions. On the contrary, absence of earthworms may serve as an indirect signal of soil degradation (Атлавините, 1990; Ivask and Kuu, 2006). Several authors reported negative effects of intensive agriculture on soil organisms, in particular earthworms. Soil treatment has a negative effects on soil water content, aeration and organic matter as well as can mechanically damage earthworms (Lee, 1985; Topoliantz *et al*., 2000; Kladivko-Eileen, 2001). Monocultures can also have an adverse effect on earthworm populations, while perennial grasses improve the living conditions of worms (Edwards and Lofty, 1975; Paoletti, 1999). Also, intensive application of inorganic fertilizers may cause a decline in earthworm populations, while organic fertilizers stimulate earthworm activity (Lofs-Holmin, 1983; Werner, 1990; Атлавините, 1990). The effect of various pesticides on earthworms differs. Most of the fungicides and organochlorine and organophosphorus pesticides are toxic to earthworms (Lee, 1985; Атлавините, 1990; Topoliantz *et al*., 2000; Burrows and Edwards, 2004). However, the effect of herbicide effects is not conclusive. After some herbicide application, even earthworm population growth has been observed, evidently due to an increase in the food material — dead weed residues (Атлавините, 1975; Lee, 1985; Werner, 1990; Атлавините, 1990). Studies in Estonia and Lithuania showed also that soil moisture was one of the most limiting factors for earthworms and that their density is correlated with rainfall over the years (Атлавините, 1975; 1990; Ivask *et al*., 2006; Ivask and Kuu, 2006).

Studies under field conditions are difficult to carry out. While field experiments are mostly focused on assessment of impact of a single factor, in real field conditions earthworms are exposed to a large set of natural and anthropogenic factors. Interactions of those factors are difficult to model in the framework of a field experiment.

Most of the agricultural land in Latvia is still under the impact of intensive agriculture. There were very few data on changes in soil properties due to these impacts. There is also very limited information on soil fauna of agricultural soils as indicators of changes of soil condition under intensive agricultural practice.

In 1992, the State Agricultural Monitoring programme was launched to fill the gaps in knowledge on processes in agricultural soils (Anonīms, 1994). A set of representative monitoring sites covered the most common soil types in Latvia in different regions (Karklins *et al*., 1998). Besides determination of soil chemical and physical properties, a special subprogramme on earthworms was also included. Due to institutional changes and lack of financing the monitoring programme was terminated in 1998. Therefore, the obtained data cannot be regarded as a long-term study, and provides only limited insight into the dynamics of agricultural soil ecosystems.

The aim of the present paper is to determine the effects of environmental factors and agricultural practice on earthworm abundance, using the earthworm monitoring data. Significance of earthworm communities in bioindication is discussed in connection with possible use of earthworms for assessment of soil conditions.

MATERIALS AND METHODS

Studies of earthworms in the framework of the State Agricultural Land Monitoring Programme were performed during 1992–1998 at six sites with different soil types: sod podzolic sand and loamy sand soils, sod podzolic gleyic loam soils, sod calcareous loam soils and fen peat soils. Sample plots (10 × 10 m) were established on arable lands used for growing different crops and grasses for several decades in crop rotation. Sampling of earthworms was performed each year in September/October. Soil samples were taken by corer (surface area 72.38 cm^2) to a depth of 25 cm. At each sampling time, 30 random samples were taken per plot. Earthworms were collected by hand sorting of soil monoliths.

The data on soil chemical and physical properties, tillage and fertilization were obtained from the State Agricultural Land Monitoring Programme (Anonīms, 1994). These data included long-term observations of agricultural soil properties under natural and anthropogenic pressure as well as data on the average monthly temperature and precipitation from the nearest meteorological stations located in Rīga, Dobele and Priekuļi.

For statistical analysis, Microsoft Office Excel 2003 was used. ANOVA and the F-test ($\alpha = 0.05$) was used to test for differences between mean densities of earthworms. Prior to analysis the data were log transformed.

Sample plot characteristics. Plots were established in six sites. Data on soil properties, crops and soil tillage at the sites are shown in Table 1 and Table 2.

Two plots were established near **Priekuļi,** near Cēsis town, in very southern part of the Northern Vidzeme glacial lowland at the foot of the Vidzeme interlobate upland. Sample plot Priekuļi 1 (57°18'29" N; 25°20'26" E) represented the higher and Priekuļi 2 (57°18'26" N; 25°20'25" E) the lower position within the local relief. During the study period, the soils in both sample plots were intensively cultivated. Rotation of crops was carried out each year. Fields were regularly treated with pesticides and fertilized with NPK (nitrogen, phosphorus, potassium) inorganic fertilizers. As organic fertilizer the plots received only green manure from plant residues.

Table 1

CHEMICAL CHARACTERISTICS (PH $_{KCL}$, ORGANIC MATTER) AND TEXTURE OF SOILS UPPER LAYER (0–20 CM) IN SAMPLE PLOTS

Sample sites	pH_{KCl}	Organic matter %	Soil texture	
			Physical clay %	Groups
Baldone	5.5	3.2	9	Sandy
Baldone P	5.2	89	–	Peat
Dobele 1	7.2	1.4	29	Loamy
Dobele 2	7.2	2.4	23	Loamy
Priekuļi 1	5.4	1.8	19	Sandy loam
Priekuļi 2	4.5	1.9	19	Sandy loam

Two plots were established near **Dobele,** located east of the Dobele town in the till plain of the Central Latvian Lowlands. Sample plot Dobele 1 (56°37'12" N; 23°19'16" E) represented the higher and Dobele 2 (56°37'12" N; 23°19'18" E) the lower position within the local relief. During the study period, the soils in both plots were intensively cultivated. Crop rotation was carried out each year. For several years, the fields were treated with pesticides and fertilized with NPK inorganic fertilizer. Only green manure in the form of plant residues was applied as organic fertilizer.

The **Baldone** (56°45'4" N; 24°20'12" E) site was located in NW corner of the Upmale hilly plain of the Central Latvian Lowland where glacial landscape is altered to some extent by melt water activity and aeolian processes. One plot was established on a lower position within the local relief. During the study period, the field where the plot was placed was used as a permanent pasture with cocksfoot (*Dactylis glomerata*) as the dominant grass. In 1992, the field was fertilized with superphosphate and potassium chloride, and in 1994, with liquid ammonium polyphosphate.

The **Baldone P** (56°45'44" N; 24°18'51" E) site was located in a drained bog area. The plot was placed in a field used as permanent pasture. In 1992, the plot was fertilized with superphosphate and potassium chloride fertilizer, and was limed.

RESULTS

Species richness. In total, six earthworm species were found at the study sites: *Allolobophora chlorotica chlorotica* (Savigny, 1826); *Aporrectodea caliginosa caliginosa* (Savigny, 1826); *Aporrectodea rosea rosea* (Savigny, 1826); *Dendrobaena octaedra* Eisen, 1974; *Lumbricus terrestris* Linnaeus, 1978; *Lumbricus rubellus rubellus* Hoffmeister, 1843. Only two species were present in all sample plots: *Aporrectodea caliginosa* and *Lumbricus rubellus*. The highest number of species (5) was recorded in clay

Table 2

AGRICULTURE MANAGEMENT (CROPS, FERTILIZERS, PESTICIDES) IN SAMPLE PLOTS DURING THE OBSERVATION PERIOD (1992–1998)

Year	1992	1993	1994	1995	1996	1997	1998
				Dobele			
Crops	Perennial grasses	Winter wheat	Winter wheat	Barley	Sugarbeet	Sugarbeet	Wheat
Organic fertilizer t/ha*	-	80	-	-	-	-	-
NPK** fertilizer kg/ha	173	792	100	-	250	450	200
Herbicides	-	+	-	-	+	+	+
Fungicides	-	+	-	-	-	-	-
				Priekuļi 1			
Crops	Perennial grasses	Winter rye	Potato	Winter wheat	Barley	Alsike clover	Potato
Organic fertilizer t/ha*	-	50	40	40	-	-	-
NPK fertilizer kg/ha	55	665	370	440	200	-	500
Herbicides	-	+	+	+	+	+	+
Fungicides	-	-	+	-	-	-	+
Desiccants	-	-	-	-	-	-	+
				Priekuļi 2			
Crops	Perennial grasses	Winter rye	Potato	Winter wheat	Barley + clover	Red clover	Barley + peas
Organic fertilizer t/ha*	-	50	40	40	-	-	-
NPK fertilizer kg/ha	55	665	370	440	200	-	250
Herbicides	-	+	+	+	+	-	+
Fungicides	-	-	+	-	-	-	-
				Baldone			
Crops				Perennial grasses			
Inorganic fertilizer	+	-	+	-	-	-	-
				Baldone P			
Crops				Perennial grasses			
Inorganic fertilizer	+	-	-	-	-	-	-

* straw ploughed in each autumn

** nitrogen, phosphorus, potassium

soils in both Dobele plots, and the lowest (only two species) was recorded in the Priekuļi 1 site with loamy sand soils (Table 3).

Species communities. Dominance of *Aporrectodea caliginosa* was observed in plots with intensive soil treatment (Dobele 1, Dobele 2, Priekuļi 1, Priekuļi 2), and at a slightly lower level in permanent pasture with sandy soil (Baldone). However, in peat soil the dominant species was *Lumbricus rubellus*, in a community with three species (Table 3; Fig. 1).

Effects of terrain and soil type. The highest density of earthworms was recorded in the Dobele sample plots with loamy soils, with maximum values in 1994 and 1995 (Fig. 2). There where no significant differences in earthworm abundance between terrain positions ($\alpha = 0.05$) (Fig. 3).

A relatively low earthworm density was found in the Priekuļi plots with sandy loam soils. The lowest density was found at the higher terrain position. The density remained significantly higher in the lower terrain position (Priekuļi 2) during the entire study period ($\alpha = 0.05$).

Earthworm density was high in pasture with sandy soils (Baldone) and low in peat soil (Baldone P) (Fig. 2; Fig. 3).

Effects of meteorological factors. In general, the annual dynamics of earthworm populations in sample plots depended on precipitation intensity during activity period of worms (April – September). In years with increased rainfall, the abundance of earthworms increased (Table 3; Fig. 4).

Tillage effects. Plots in Priekuļi and Dobele were subjected to intensive agrotreatment during the entire observation period, while both Baldone plots, which were used for pasture, received almost no agricultural management (Table 2). The earthworm density dynamics differed in these sample plots. The intensively cultivated plots in Dobele in 1994 and 1995 had maximum worm abundance, while one of the lowest numbers of worms was observed in 1994 in the Priekuļi plots. During the observation period, in loamy, sandy loam and peat soils, irregular fluctuation of earthworm density was observed. In Baldone plot with low intensity of cultivation, a statistically significant increase of density in 1992–1995 ($\alpha = 0.05$) was observed followed by a gradual decrease in 1996–1998 which was not statistically significant (Table 3; Fig. 2).

Table 3

MEAN DENSITY (ind. m^{-2}) AND RELATIVE NUMBERS (%) OF EARTHWORM SPECIES IN SAMPLE PLOTS DURING THE OBSERVATION PERIOD (1992–1998)

Specimen	1992	1993	1994	1995	1996	1997	1998	% Total
Dobele 1								
Aporrectodea caliginosa	68	136	323	277	49	182	80	96
Aporrectodea rosea	5	2	0	0	0	0	0	
Allolobophora chlorotica	0	5	0	0	0	0	0	
Lumbricus terrestris	0	0	0	2	2	0	0	
Lumbricus rubellus	0	10	0	0	0	12	5	2
Total	73	153	323	279	51	194	85	100
Dobele 2								
Aporrectodea caliginosa	34	153	270	384	146	148	194	97
Aporrectodea rosea	12	0	0	0	0	0	0	
A. chlorotica	2	0	0	0	0	0	0	
Lumbricus terrestris	0	0	0	0	2	3	0	
Lumbricus rubellus	0	5	5	0	5	7	0	2
Total	48	158	275	384	153	158	194	100
Priekuļi 1								
Aporrectodea caliginosa	24	32	15	83	24	92	39	95
Lumbricus rubellus	5	5	5	0	0	0	0	5
Total	29	37	20	83	24	92	39	100
Priekuļi 2								
Aporrectodea caliginosa	58	100	63	58	49	114	158	84
Lumbricus terrestris	0	0	0	10	0	0	0	1
Lumbricus rubellus	22	46	12	5	5	5	10	15
Total	80	146	75	73	54	119	168	100
Baldone								
Aporrectodea caliginosa	49	109	190	209	112	175	138	88
Lumbricus terrestris	0	0	0	5	0	0	0	
Lumbricus rubellus	0	22	7	19	61	0	10	11
Dendrobaena octaedra	0	0	0	0	5	0	5	
Total	49	131	197	233	178	175	153	100
Baldone P								
Aporrectodea caliginosa	10	15	7	12	15	5	61	34
Allolobophora chlorotica	0	0	0	0	0	0	2	
Lumbricus rubellus	24	36	15	41	24	36	22	54
Dendrobaena octaedra	5	10	0	5	10	5	10	12
Total	39	61	22	58	49	46	95	100

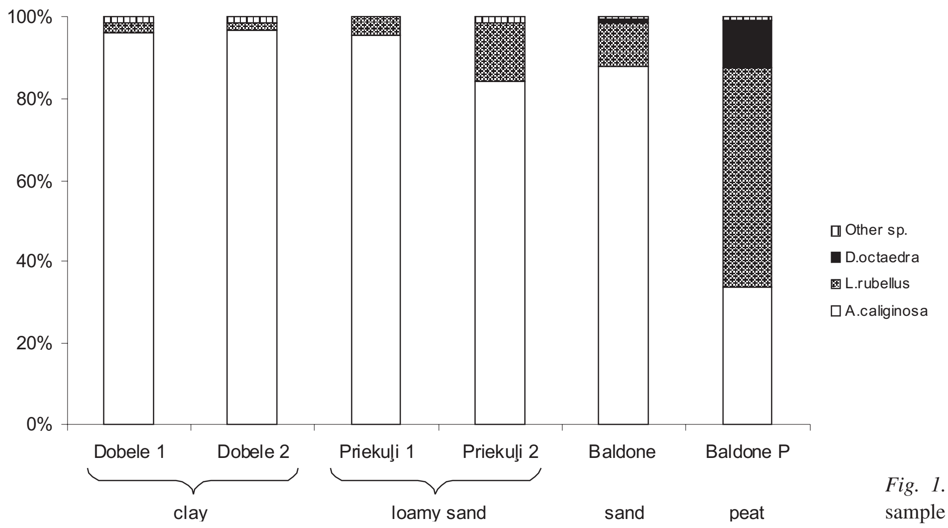

Fig. 1. Mean relative abundance of earthworms in sample plots.

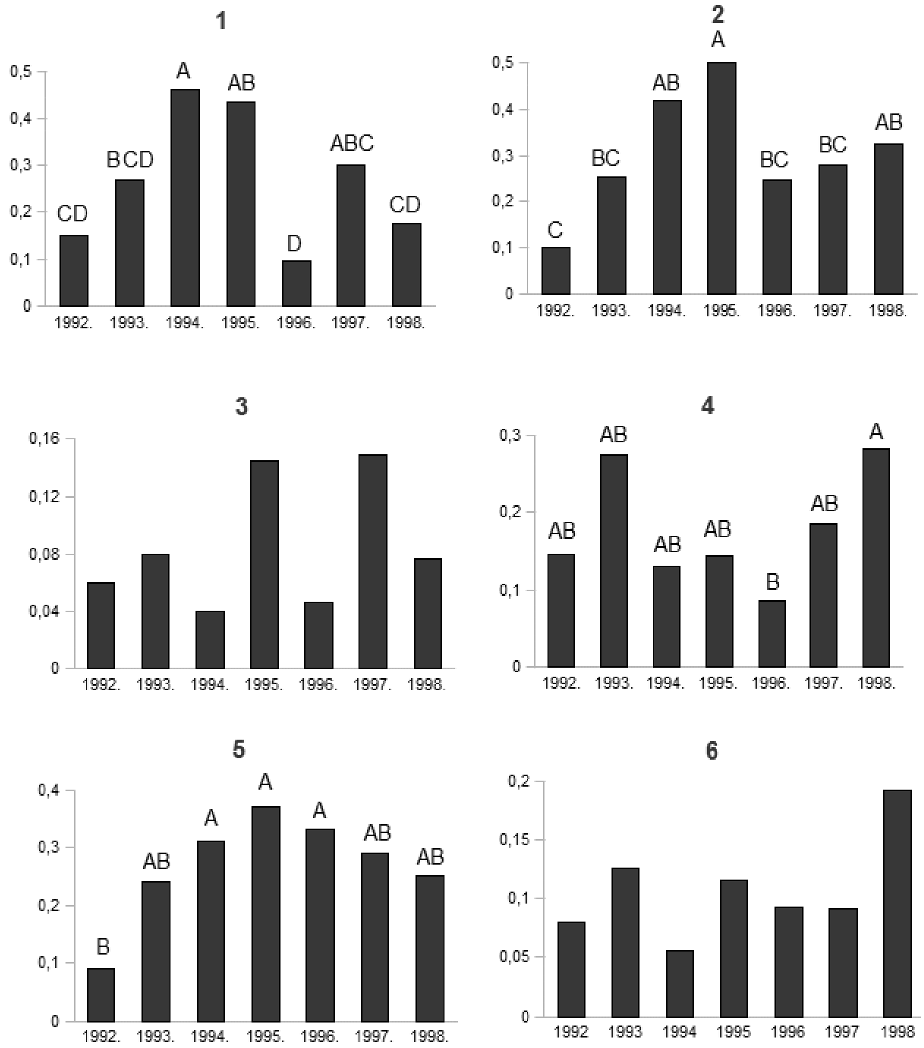

Fig. 2. Earthworm mean density in different years. Columns having equal letters are not statistically different (α = 0.05). 1 – Dobele 1; 2 – Dobele 2; 3 – Priekuļi 1; 4 – Priekuļi 2; 5 – Baldone; 6 – Baldone P.

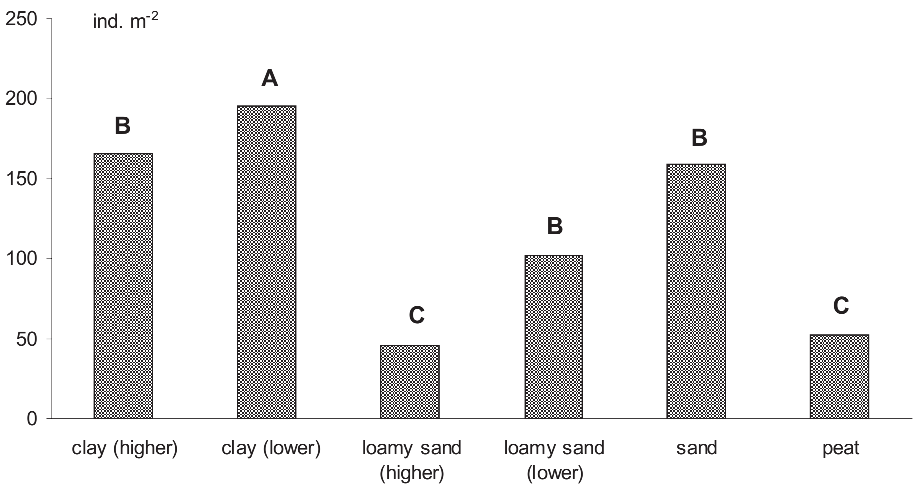

Fig. 3. Mean densities of earthworms in various soils with different terrain position. Columns having equal letters are not statistically different (α = 0.05)

DISCUSSION

Dominance structure and species associations. All collected six species of earthworms are common for agricultural soils of the Baltic region (Эглитис, 1954; Атлавините, 1990; Ivask *et al.*, 2007). The only dominant species in plots with intensive soil treatment (Priekuļi, Dobele) was *Aporrectodea caliginosa*. Populations of other species were low or not present in soils managed intensively (Fig. 1). In contrast, under permanent pasture on loamy soils, earthworms formed a community consisting of two dominant species *Aporrectodea caliginosa* and *Allolobophora chlorotica* (Ventiņš, 2009; unpublished data of the author). Species such as *Allolobophora chlorotica*, *Aporrectodea rosea*, *Lumbricus rubellus* and *L. terrestris* are sensitive to intense and long-term tillage and can be significantly re-

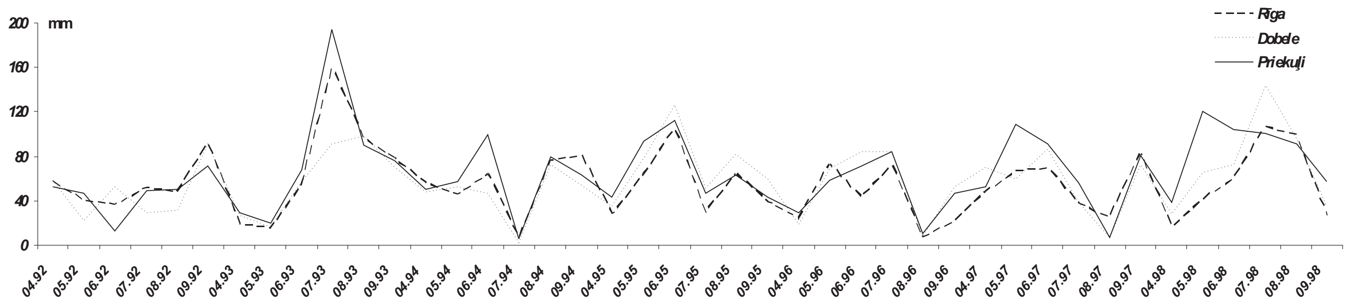

Fig. 4. Mean monthly precipitation during the observation recorded in three meteorological stations (Rīga, Dobele, Priekuļi) located in the same region as sampling plots.

duced in the numbers or even disappear under these conditions (Эглитис, 1954; Lewis, 1980; Атлавините, 1990; Pižl, 1992). However, moderate cultivation may be beneficial for *Aporrectodea caliginosa* (Edwards and Lofty, 1973; Ivask *et al.*, 2006).

In permanent pasture with sandy soil (Baldone), *Aporrectodea caliginosa* dominance was high, but a higher proportion of *Lumbricus rubellus* was observed. In peat soils the dominant species was *Lumbricus rubellus.* In a community that included *Lumbricus rubellus, Aporrectodea caliginosa,* and *Dendrobaena octaedra* (Fig. 1). Usually, *Dendrobaena octaedra* and *Lumbricus rubellus* appear already on the early stages of soil development after establishing tillage in drained peat soils, while the humus former species such as. *Aporrectodea caliginosa* forms larger populations in a developed humus horizon (Перель, 1979; Pižl, 1992).

Main factors affecting density of earthworms

Effect of terrain and soil type. Loamy and sandy loam soils are most favourable for earthworms, as they occur in higher densities in contrast to sandy soils (Атлавините, 1975). Despite intensive cultivation, earthworms were the most abundant in loamy soils in the Dobele sample plots. However, in Priekuļi sandy loam soils the earthworm density throughout the observation period was low. This is difficult to explain as the interactions between the effect of tillage and soil type on earthworms are still not understood. In sandy soils of permanent pasture earthworms reached a relatively high density. In peat soils density was relatively low apparently reflecting a particular stage of formation of the humus horizon (Fig. 3).

The terrain level appeared to be an explanatory factor associated with earthworm population density. On the raised fields and slopes earthworms usually are not very abundant because of intense soil erosion (Атлавините, 1975, 1990; Lee, 1985). Earthworms were more abundant in the relief depressions. In the Dobele 2 plot earthworm density was significantly higher (α = 0.05) than in the Dobele 1 plot. Also in sandy loam soils of the Priekuļi plot, density of worms was significantly (α = 0.05) higher then in soil of the lower terrain (Fig. 3).

Effect of meteorological conditions. One of the most important factors affecting earthworm abundance is precipitation especially during the periods of worm activity in April – October. In general, increased abundance of earthworms is observed after periods of high precipitation, and after prolonged drought substantial reduction in number of worms occurs (Lee, 1985).

Dynamics of earthworm density in the monitoring plots can be explained largely by variation of meteorological conditions in different years (Fig. 2; Fig. 4). Earthworm abundance decreased significantly (α = 0.05) during prolonged periods of drought in 1992 and 1996 in intensively managed soils (Dobele, Priekuļi). In contrast, under the favourable moisture conditions prevailing in summer of 1993, 1995 and 1997–1998, an increase of earthworm density was observed. After summer droughts, the number of earthworms usually was significantly reduced. During spring drought the soil still contains enough moisture from melting snow and earthworms were not strongly affected. In summer in 1994, a severe drought was recorded (Fig. 4) causing a significant decrease in earthworm density in Priekuļi 1 and Baldone P. During this period, in the Dobele sample plots, significant increase in the number of worms was observed. In the pasture at Baldone the impact of meteorological factors had less effect on tearthworm density (Fig. 2; Fig. 4), and in 1994 and 1995 an increase in the number of worms was observed. Apparently perennial vegetation may significantly reduce the effects of unfavourable climatic factors, providing more even distribution of worms in the soil (Fig. 2).

Since *Aporrectodea caliginosa* was dominant, fluctuations in the number of this species in general caused changes in the total density of worms. An obligatory diapause occurs in *Aporrectodea caliginosa* in July, which usually lasts until the mid of August. The period of diapause may vary in different years and plots. During diapause worms prefer to stay at the depth of 30–40 cm (Lee, 1985). Therefore, drought in July in various plots may have a different effect on worm abundance compared to the effect in September/October, when the worms were collected (Fig. 2; Fig. 4). It is possible that drought in June or August and September, when *Aporrectodea caliginosa* is active and feeds in the upper layers of the soil, was most critical for this species. However, confirmation of this requires further investigation.

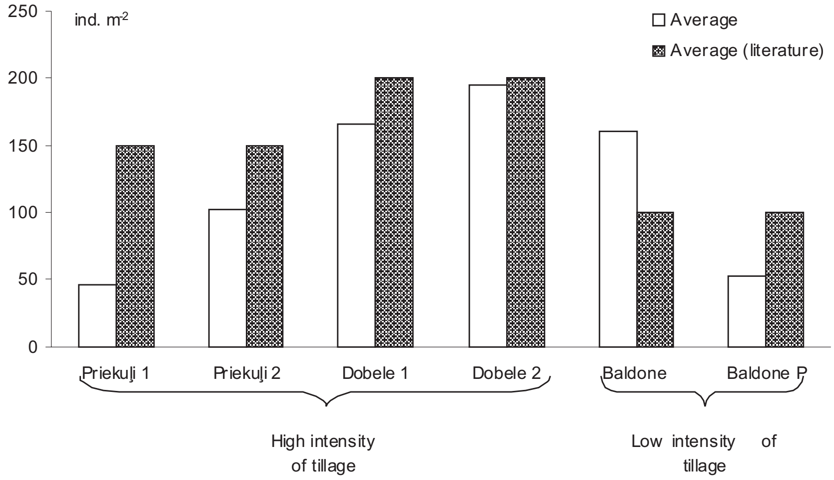

Fig. 5. Density of earthworms in plots with different intensity of soil tillage in comparison with average literature data* obtained from the Baltic region.

* Literature: Эглитис, 1954; Атлавините, 1975, 1990; Ivask *et al*., 2006; Ivask and Kuu, 2006.

Effects of tillage. The density and composition of earthworm communities are good bioindicators for assessment of the agricultural soil quality. Mechanical soil disturbance by intensive tillage significantly reduces density and diversity of earthworms (Lee, 1985; Атлавините, 1990). In arable lands with sustainable agriculture practices on sandy soils, *Aporrectodea caliginosa* can be found along with *Lumbricus rubellus* and *L. terrestris* in significant numbers. More fertile loamy sand and loam soils not subjected to soil treatment have more diverse earthworm communities. In general, earthworm communities composed of less than 3–5 species can be regarded as indicators of possible degradation of agricultural soils (Ivask *et al*., 2007). In drained fen peat soil, the dominant species were acidotolerant *Lumbricus rubellus* and *Dendrobaena octaedra*. *Aporrectodea caliginosa* is also common species in acid soils, but this species usually inhabits the peat later after at a certain decomposition stage (Атлавините, 1990). Typical earthworm density recorded in arable fields on loamy sand and loamy soils in the Baltic region is more than 200 ind. m^{-2}, and on sandy soils 100–150 ind. m^{-2} (Эглитис, 1954; Атлавините, 1975; 1990; Ventiņš u.c., 2000; Ivask *et al*., 2006; Ivask and Kuu, 2006; Ventiņš, 2009) (Fig. 5).

The Dobele plots with loamy soil formed a suitable living environment for earthworms (Fig. 3). Also, more acidic soils in Priekuļi were suitable for worms. However, stable populations in these plots were established only by *Aporrectodea caliginosa* (Fig. 1). Obviously, regular tillage and excessive use of pesticides, inorganic fertilizers and monocultures have suppressed other species, as plots in Dobele and Priekuļi were regularly treated with herbicides (Table 2). Only *Aporrectodea caliginosa* seemed to be less sensitive to agricultural practices and was found in larger numbers. A single use of herbicides has not been reported to have strongly adverse effect on earthworms, while after multiple applications only *Aporrectodea caliginosa* can survive (Lee, 1985; Werner, 1990; Атлавините, 1990; Атлавините, 1995). Fungicides are much more toxic for earthworms and can cause a considerable decrease in worm density (Burrows and Edwards, 2004). The Priekuļi 1 plot was subjected to several fungicide treatments during the study period (Table 2). This could be one of the negative factors responsible for relatively large annual fluctuations in numbers of worms (Fig. 2).

Application of organic fertilizers usually provides more favourable conditions (nutrient availability) and promotes reestablishment of earthworm populations, due to return of plant residues to the soil (Атлавините, 1975; Werner, 1990; Атлавините, 1990l; Pižl, 1992). An increase of abundance of earthworms was observed in the Dobele plots after soil fertilization with manure in 1994–1995. The Priekuļi plots were fertilised with manure in 1993–1995, but this had only a small positive effect on earthworm populations (Fig. 2; Table 2).

The effect of inorganic fertilizers on earthworm populations is not clear (Lee, 1985). It has been reported (Атлавините, 1975; Lee, 1985) that NPK fertilizer in concentrations of 100– 260 kg/ha have a positive effect on earthworms. Fertilizer application promotes plant productivity, which indirectly improves food supply for earthworms. However, higher concentrations of NPK have toxic effects (Атлавините, 1975; Lee, 1985). High doses of NPK fertilizer were applied in Priekuļi and also in Dobele in some years (Table 2), which might have had a negative effects on the total density of earthworms. A significant decrease of worm density in Priekuļi in 1994 can be attributed to high doses of NPK fertilizer applied in 1993 (Fig. 2).

Mostly annual crops were grown in the Priekuļi and Dobele plots during the study period, which is much less favourable than perennial crops for earthworms, due to repeated soil treatment during a year (Table 2). The Baldone and Baldone P plots, which had a low intensity of soil disturbance and perennial vegetation were characterized by variable species dominance structure and less variability of worm number. The gradual decrease in earthworm density in the Baldone plot after 1995 can be explained by reduction of fertilizer effect after application of ammonium polyphosphate in 1994 and a possible subsequent reduction of food resources for worms (Fig. 2; Table 2).

Table 4

MAIN CHARACTERISTICS OF SAMPLE PLOTS AND RESPONSE OF EARTHWORM COMMUNITIES TO THESE CHARACTERISTICS ACCORDING TO LITERATURE DATA[1]

Sample plots	Soil types	Plot position (higher - lower)	Intensive cultivation	Perennial grasses	Annual crop rotation	Maximal abundance ind. m^{-2} Favourable weather conditions	Minimal abundance ind. m^{-2} Unfavourable weather conditions	Mean abundance ind. m^{-2} Literature data *
Priekuļi 1	+	-	-	-	-	92.3	24.3	~150
Priekuļi 2	+	+	-	-	-	167.6	80.1	~150
Dobele 1	+	-	-	-	-	323.0	51.0	200
Dobele 2	+	+	-	-	-	383.7	48.6	200
Baldone	-	+	+	+	+	233.1	48.6	100-150
Baldone P	-	+	+	+	+	94.7	38.9	~100

[1] + favourable for earthworms; - unfavourable for earthworms. * Literature: Эглитис, 1954; Атлавините, 1975; 1990; Ivask *et al*., 2006; Ivask and Kuu, 2006; Ventiņš, 2009

Effects of interactions of factors. Soil texture and orographic field position were key factors in explaining earthworm population structure in the agrocenosis. Annual population changes usually were associated with weather conditions, particularly rainfall, and soil tillage. Soil tillage also affected earthworm species composition (Table 4). Earthworm density significantly decreased under unfavourable weather conditions in fields managed by intensive farming methods (Priekuļi plots in 1994; Dobele and Priekuļi plots in 1996) (Fig. 2). The maximum numbers of worms usually corresponded to periods with favourable meteorological conditions. A lower position of fields in the terrain have a positive effect on earthworm populations, while intensive tillage methods such as plowing, monocultures, and treatment with fertilizer and pesticides have negative effect (Атлавините, 1975; 1990; Lee, 1985). When seasonal meteorological conditions were favourable, in the loamy soils (Dobele 1 and Dobele 2) worm density increased and significantly exceeded the average values, regardless of field orographic position and cultivation of the soil. In sandy loam soils (Priekuļi 1 and Priekuļi 2), intensive tillage had more pronounced effects. In not treated soil (pasture — Baldone) earthworms reached high density even in sandy soils. Regardless of the tillage methods, after a prolonged drought (in 1996), earthworm populations declined at all sites. Soil management was an additional stress factor on worms during seasons with adverse meteorological conditions. Under favourable meteorological conditions in loamy soils the negative impact of soil management to earthworms was significantly reduced (Fig. 2; Table 4). Presumably, in loamy soils, which support large earthworm populoations, it was not sometimes possible to identify the negative effect of tillage on earthworm density (Table 4). In this case a better indicator to evaluate negative effect is earthworm species composition and changes in dominance structure (Ivask *et al*., 2006). Intensively treated fields were characterized by dominance of a single species *Aporrectodea caliginosa*. In fields with less intense soil tillage, the numbers of more sensitive earthworm species increased.

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SLIEKU (*Oligochaeta, Lumbricidae*) POPULĀCIJU DINAMIKA LATVIJĀ IZPLATĪTĀKAJOS LAUKSAIMNIECĪBAS AUGŠŅU PAVEIDOS

Pētījumi par slieku populācijām tika veikti no 1992. gada līdz 1998. gadam lauksaimniecības zemes pārraudzības programmas ietvaros Latvijā izplatītos augšņu paveidos. Pētījumi tika veikti saistībā ar augsnes tipu, vietas orogrāfiju, pielietotajiem agrotehniskajiem pasākumiem un meteoroloģiskajiem apstākļiem. Kopā tika atrastas sešas slieku sugas. Tikai divas sugas, *A. caliginosa* un *L. rubellus*, tika atrastas visos parauglaukumos. Lielākais slieku blīvums konstatēts smilšmāla augsnēs ar zemāku reljefa novietojumu, zemākais — smilts augsnēs ar augstāku reljefa novietojumu. Intensīvi kultivētās platībās slieku blīvums un sugu daudzveidība samazinās. *A. caliginosa* dominance te ir tuva 100%. Ganībās slieku sugu daudzveidība palielinās. Blīvuma dinamika lielā mērā bija saistīta ar meteoroloģiskajiem apstākļiem. Tomēr labvēlīgos meteoroloģiskajos apstākļos mālainās augsnēs kultivācijas negatīvā ietekme netika novērota, savukārt mālsmilts augsnēs agrotehnisko pasākumu negatīvā ietekme bija daudz izteiktāka. Ganībās slieku blīvums sasniedza augstas vērtības pat smilts augsnēs.