PAN
POLSKA AKADEMIA NAUK

JOURNAL OF WATER AND LAND DEVELOPMENT

e-ISSN 2083-4535

ITP-PIB

Polish Academy of Sciences (PAN) Institute of Technology and Life Sciences – National Research Institute (ITP – PIB)

JOURNAL OF WATER AND LAND DEVELOPMENT
DOI: 10.24425/jwld.2021.139945
2022, No. 52 (I–III): 66–74

The soil aggregate structure as a marker of the ecological niche of the micromollusc *Vallonia pulchella*

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RECEIVED 21.07.2020 REVIEWED 01.12.2020 ACCEPTED 28.12.2020

Abstract: The article discusses the role of the soil aggregate structure in quantifying the marginality and specialisation axes of the ecological niche of the micromollusc *Vallonia pulchella* (Muller 1774) that inhabits technosols. The experimental polygon consisted of 105 samples located within 7 transects (15 samples each). The distance between rows of sampling points was 3 m. The average density of *V. pulchella* was 1393 ind.$\cdot$m^{-2}. The soil aggregate fraction of 1–5 mm was found to be predominant within the technosol. The spatial variation of aggregate fractions was characterised by a moderate level of the spatial dependence. It was impossible to choose an adequate covariance model from among the traditional ones to interpolate the spatial variation of aggregate fractions, and only the Matérn model was best suited. The axis of marginality and specialisation of the *V. pulchella* ecological niche projected in soil aggregate fractions was significantly different from a random alternative. The ecological niche of the *V. pulchella* was presented by integral variables, such as the axis of marginality and specialisation, which were the basis to build a map of the spatial variation of the habitat suitability index. The marginality of the *V. pulchella* ecological niche correlates with soil penetration resistance indicators at depths ranging from 0–5 to 20–25 cm, soil humidity, acidity, and aeration. The specialisation correlates with the soil mechanical impedance at 25–35 cm, nitrogen content, and the soil acidity regime.

Keywords: ecological niche, geostatic analysis, habitat, Matérn model, phytoindication, soil mechanical impedance

INTRODUCTION

Aggregates are the main component of the soil structure, which allows to measure its physical state as an environment for living organisms. Soil structure affects soil moisture content, infiltration capacity, erodability, circulation of nutrients, stabilisation of organic matter, root penetration, productivity of natural plant communities, and crop yields [CHAPLOT COOPER 2015]. The aggregate stability is used as an indicator of the soil structure [MUSTAFA *et al.* 2020]. The structure and stability of soil aggregates is the most important, since enables to examine conditions for increasing agronomic productivity and reducing soil erosion [ZHANG *et al.* 2016]. Aggregation of soil was studied mainly in the agricultural context. A study [WILPISZESKI *et al.* 2019] examined the role of tillage, soil texture, and the presence of carbon in the agricultural land as factors that influence the aggregate structure. In the process of land reclamation, it is important to select optimal management strategies to create not only the desired vegetation cover, but also to promote the preservation of the macroaggregate structure in soils to improve long-term nutrient supply and physical properties of soil [WICK *et al.* 2016].

Aggregation processes in soil are the result of interaction of a number of physical, chemical and biological factors with the complex feedback mechanisms [RIVERA, BONILLA 2020; SODHI *et al.* 2009]. The soil aggregation is regulated by the biota [DUCHICELA *et al.* 2013]. In soils where organic matter is a major aggregate binding agent, a link can be established between aggregate size distribution and soil biological functions [JASTROW, MILLER 1998]. The role of biodiversity in soil aggregation is of particular interest [DELGADO-BAQUERIZO *et al.* 2017; WAGG *et al.* 2014]. There are different mechanisms of soil biota influence on the aggregation of soil [LEHMANN, KLEBER 2015; SIX *et al.* 2004]. Bacteria are known to be able to synthesise biopolymer that acts as binder [DENG *et al.* 2015], and the mushroom mycelium can entangle soil particles to keep them together. Earthworms, insect larvae, and other large soil animals may stabilise the aggregate structure [Bertrand *et al.* 2005]. Soil saprophages consume the soil and mix it with their intestinal content. After digestion, the mixture takes the form of a highly structured formation, such as casts or coprolites [Gorres, Amador 2010]. The spatial variation of soil aggregate structure can influence the organisation of the soil macrofauna community. The soil aggregates also help to form the unique ecological isolation of the microbial community in the soil. Soil aggregates can serve as a refuge for microbes from predators [Rillig *et al.* 2017]. There are practically no researches into the influence of soil aggregate structures on functional features of mollusc populations. It is possible, that organic substances in the soils have a indirect impact on the molluscs. This requires a deep understanding of the structure and formation of aggregates [Lehmann, Kleber 2015].

The concept of the ecological niche plays a central role in the modern ecology [Holt 2009; Hutchinson 1957]. A set of biotic and abiotic conditions under which a given organism can survive and reproduce is considered as its ecological niche [Hutchinson 1957]. The ecological niche may be understood in the context of the two dimensions: Grinnellian and Eltonian. The Grinnellian niche takes into account the importance of a given set of resources for the survival of a species [Devictor *et al.* 2010; Grinnell 1917]. The Grinnellian niche is considered in two ways: as a complex of the habitat conditions and as behavioural adaptations allowing organisms to persist and produce offspring [Grinnell 1917]. The Eltonian niche is based not only on the consideration of species response to the environment impact but on the species impact on the environment. The niche reflects place of a species in the biotic environment, and its relations to food and enemies [Elton 1927]. Hutchinson suggested that an ecological niche should be considered as a hyper-volume in the multidimensional space, where species could potentially support the viability of their populations under the influence of environmental conditions [Hutchinson 1957]. Thus, the use of the term “niche” is advisable both in the relation to the organism and in the relation to the population or the species.

The habitat preferences of land molluscs were studied in the ecosystems that differed in vegetation, soil type, and moisture level [Kunakh *et al.* 2008b; Millar, Waite 1999]. Among climatic factors, temperature and humidity have the greatest impact on land molluscs. Other climatic factors much less, or indirectly, affect molluscs, e.g. changes in humidity and temperature. The calcium concentration and the pH value correlated with it are the most significant soil parameters that influence snails [Hotopp 2002]. The terrestrial molluscs are able to fix calcium due to intracellular and extracellular biomineralisation, since their shells are an important source of calcium for other animals. Soil moisture has also been detected as an essential factor in the diversity of terrestrial snail fauna [Čejka, Hamerlík 2009]. The available soil moisture is an important ecologic factor for the biota of reclaimed land. The degree of human-induced ecosystem transformation can be assessed through the diversity of terrestrial snail communities [Douglas *et al.* 2013]. It has been shown that a series of models that best explain the distribution of mollusc and their abundance are specific to a particular species and type of technosols, and these tend to be invariant over time [Kunakh *et al.* 2018a].

Ecological factors affecting the species distribution are in principle spatially structured, so the species community also has a spatial structure [Thuiller *et al.* 2004]. Based on Hutchinson’s concept of an ecological niche, the Factor Analysis of an Ecological Niche (ENFA) can be used for the modelling of the species geographical distribution [Hirzel *et al.* 2002]. This approach was useful for the simulation of the ecological niche of the mollusc in biotopes resulting from reclamation of degraded lands. Molluscs may also be the cause of the spatial heterogeneity of environmental regimes. The substantial contribution of snails to the nitrogen cycle was proved in a nitrogen-limited ecosystem, which can be a source of spatial heterogeneity of the higher plant production [Jones, Shachak 1994]. Some terrestrial gastropod communities cause of changes in the content of nitrogen and phosphorus in soil. This shows that the spatial and temporal dynamics of plant communities depend on the detritivore food chain structure [Thompson *et al.* 1993].

The impact of the aggregate soil structure on molluscs has not been sufficiently studied, which was an incentive to develop the study described in the article. The study includes the spatial distribution of the technosols aggregate structure (sod-lithogenic soils on grey-green clays) as a marker of the ecological niche of micromolluscs *Vallonia pulchella* (Muller 1774).

MATERIAL AND METHODS

The research was conducted at the Research Centre of the Dnipro Agrarian and Economic University in Pokrov (Ukr. Dniprovs’kyy derzhavnyy ahrarno-ekonomichnyy universytet), Ukraine. This experimental field for studying the optimal modes of agricultural reclamation was established in 1968–1970. The territory has a temperate continental climate with an average annual maximum temperature of 26.4°C and a minimum of –8.2°C, with an average annual rainfall of about 511 mm (the average for 20 years according to the Nikopol meteorological station) – Figure 1.

Sampling was conducted in June 2019. The main goal of our work was to study the spatial variation of micromolluscs. Therefore, sampling was carried out during the highest activity of animals and plants supported by optimal humidity and temperature during the year. Sampling was carried out on a variant of artificial soil (technozems) formed in sod-lithogenic soils on grey-green clays. The study was conducted in June 2019. According to IUSS WRB 2007 [IUSS… 2007], the soil belongs to the RSG Technosols. The examined profile also satisfies the criterion for the Spolic prefix qualifier having 20 percent or more artefacts (consisting of 35 percent or more of mine spoil) in the upper 100 cm from the soil surface [Yorkina *et al.* 2018].

The polygon consisted of 7 transects and each transect consisted of 15 sampling points. The distance between rows within the polygon was 3 m. A soil was sampled with a cylinder 5 cm in height and 10 cm in diameter from the centre of each sampling point. Each sample was divided into 10 sub-samples 10 g each. Each soil sample was examined in the laboratory using a 10 binocular MBS-9 microscope and the number of *V. pulchella* individuals was recorded.

The mechanical resistance of the soil was measured to a depth of 50 cm at 5 cm intervals in the field using the Eijkelkamp manual penetrometer. The average error of the measurement device was ±8%. Measurements were made with a cone of a 1 cm^2 cross section. Within each measurement point, the mechanical impedance of the soil was made in one

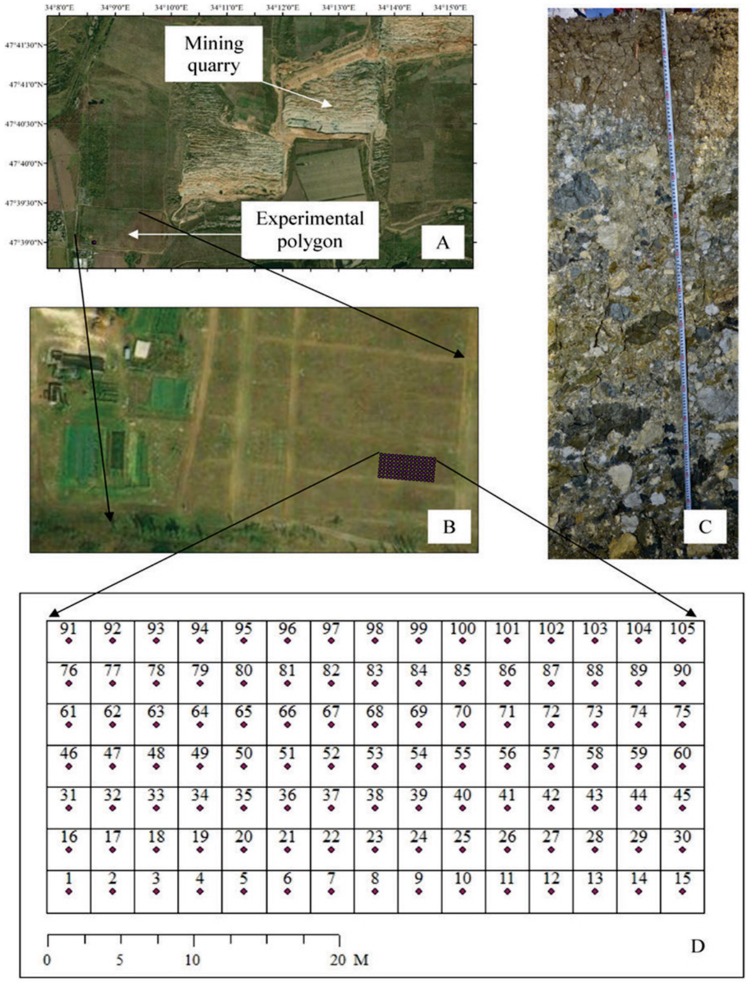


Fig. 1. Research centre for the study of optimal regimes of agricultural recultivation near Pokrov (Ukraine): A) satellite image of the study area; B) experimental polygon position; C) technosols profile; D) sampling point location within the experimental polygon; source: own elaboration

replication. The soil electrical conductivity was measured *in situ* using HI 76305 meter. The aggregate size distribution was determined in accordance with the recommended soil sampling and analysis methods [Kroetsch, Wang 2008].

Based on geobotanical descriptions of vegetation the phytoindication, the study assessed environmental factors according to Didukh [2011]. Didukh phytoindication scales include edaphic and climatic scales. The edaphic phytoindication scales include the soil water regime (*Hd*), variability of humidity (*fH*), soil aeration (*Ae*), soil acidity (*Rc*), total salt regime (*Sl*), carbonate content in the soil (*Ca*), and the nitrogen content in the soil (*Nt*). The climatic scales include thermal climate parameters (thermal regime, *Tm*), humidity (*Om*), cryo-climate (*Cr*) and the continentality of climate (*Kn*). In addition to these, the lighting scale (*Lc*) is indicated, which is characterised as a microclimate scale [Zhukov *et al.* 2018].

The geostatic analysis was carried out with the kriging method. The Matérn variogram model was used [Minasny, McBratney 2005]. This model is flexible and can reflect the various behaviour of spatial processes. On this basis, the Matérn variogram can be used to model the soil properties. The main feature of the Matérn model is the inclusion of the smoothness parameter, which is directly capable of explaining the spatial autocorrelation at close distances [Genton, Kleiber 2015]. We used the cross-validation procedure, and the normalised root mean square error (*NRMSE*), mean error (*ME*), and mean squared deviation ratio (*MSDR*) were calculated [Vasat *et al.* 2013]. The root mean square error (*RMSE*) was calculated as follows:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}\left(x_{1,i} - x_{2,i}\right)^{2}}{n}} \tag{1}$$

Normalised root mean squared error (*NRMSE*) was calculated as follows:

$$NRMSE = \frac{RMSE}{x_{1,\max} - x_{1,\min}} \tag{2}$$

Mean squared deviation ratio (*MSDR*) was calculated as follows:

$$MSDR = \frac{\sum_{i=1}^{n}\left[\frac{\left(x_{1,i} - x_{2,i}\right)^{2}}{var_{i}}\right]}{n} \tag{3}$$

where: x_1 = prediction of the variable *X*, x_2 = measure of that variable, *n* = number of the records, *var* = kriging variance.

The lower the *NRMSE*, the more accurate the map is. The *MSDR* indicates whether the variance of measurement data is well reproduced with the kriging interpolation and ideally it equals 1 [Vasat *et al.* 2013]. Spatial variations of predictors and regression models of the soil mechanical impedance were displayed using the 'Surfer®12 (www.goldensoftware.com). Statistical calculations were performed by the Statistica 7.0 software and the project for statistical computations R [R Core Team 2020] using adehabitat [Calenge 2011] and vegan [Oksanen 2017] libraries. Two-dimensional mapping, estimation of geostatistics, and creation of *asc*-files with spatial variability of the environment indicators was accomplished with the use of ArcGis 10.0 [Yorkina *et al.* 2018].

RESULTS

Air-dry soil sample of 10.5 kg was examined within the research area, in which 266 individuals of *Vallonia pulchella* (Muller 1774) were found. Thus, the average density of this species in the sod-lithogenic soils on gray-green clays was 1393 $\text{ind.}\cdot\text{m}^{-2}$. The aggregate structure analysis showed that the prevailing fraction by its content are the aggregates of 1.0–2.0 to 3.0–5.0 mm, the content of which was 18.1 ±0.12 and 23.0 ±0.09% respectively. The geostatistical analysis was carried out to determine spatial patterns of aggregate fraction distribution (Tab. 1). The spatial variation of aggregate fractions is characterised by the moderate level of spatial dependence, as it is evidenced with the SDL of 24.68–52.55% (nugget to sill ratio as an indicator of spatial autocorrelation strength). There were two local maxima of spatial dependence: for aggregate fractions of 0.5–1.0 mm and 5.0–7.0 and 7.0–10.0 mm. Correspondingly, the local minimum of spatial dependence was characteristic of the 2.0–3.0 mm aggregate fraction. The practical range of the spatial variation of aggregate fractions is in the diapason of 5.80–38.85 m.

The practical range for the variogram of the spatial variability of aggregate fraction <0.25 mm is 6.55 m. For aggregates of 0.25–0.50 mm the geostatistic was much higher and reached its maximum (38.85 m) for aggregates of 0.5–10 mm. Further, with the increasing fraction size, the practical range monotonically decreased. The Matérn model can be considered as a generalised series of theoretical variogram models [Minasny, McBratney 2005]. A Gaussian model was the most suitable as Kappa tends to infinity. The Whittle function [Whittle 1954] was the best for an aggregate fraction of 5.0–7.0 as the Kappa parameter was very close to 1.0. For aggregates with sizes 0.25–0.5, 0.5–1.0 and 3.0–5.0 mm, it is impossible to choose an adequate model from among the traditional ones, so only the Matérn model is considered the most suitable.

The geostatistical analysis enables to interpolate the value on points where measurements were not made and, on the basis of the results, we can build maps of the data spatial variation as ecogeographical variables in terms of the ecological-niche factor analysis (Fig. 2).

The content of organic matter in technosol varied within the range of 0.22–1.48% (Tab. 2). In general, water extraction acidity was slightly alkaline. The high level of salt content in water was typical for technosols. The content of carbonates varied from 11.10 to 47.30%. According to Katschinski nomenclature [Katschinski 1956], particle size distribution technosols can be qualified as silty medium clay. Analysis of the spatial variation of these soil features showed that there was no spatial variation component, so they were not used to describe the spatial patterns of micromolluscs.

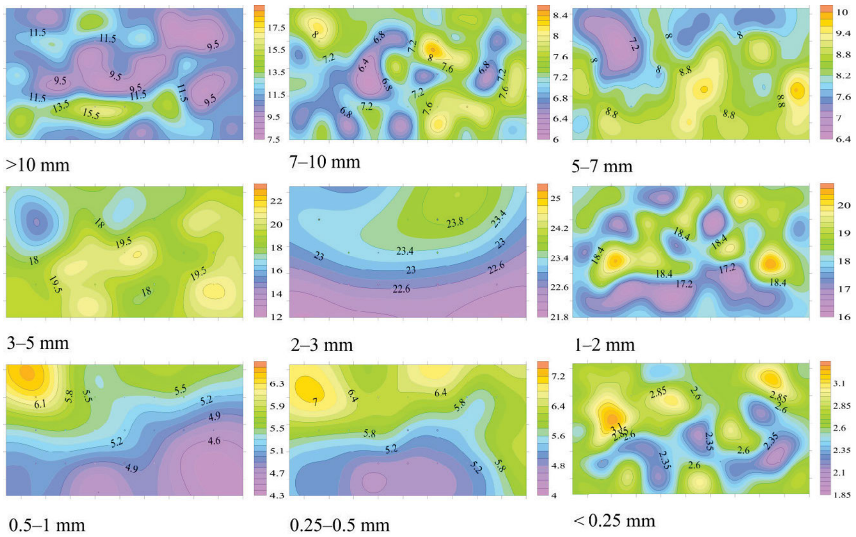
The water content increased in the profile with depth (Tab. 3). The soil bulk density did not change significantly in the profile. The density of the solid phase increased with depth. Soil porosity was within the range of 49.61–55.91%.

The distribution of the ecogeographical variables within the site may be considered as the global distribution. The information

Table 1. Descriptive statistic and geostatistic parameters of the aggregate fraction variation

Fraction (mm)	Mean ±standard error	*Phi*	Pr_Range (m)	*Sill*	Nugget	*SDL*	Kappa	*NRMSE*	*ME*	*MSDR*	R2_cross
≥10	11.2 ±0.27	0.57	6.42	4.66	3.19	40.62	→∞	0.20	−0.0009	0.65	0.36
<7.0–10.0)	7.2 ±0.06	0.59	6.60	0.31	0.15	33.15	→∞	0.24	0.0014	0.76	0.23
<5.0–7.0)	8.3 ±0.10	3.84	14.68	0.66	0.34	34.19	0.9	0.24	0.0003	0.66	0.33
<3.0–5.0)	18.8 ±0.21	2.44	12.83	2.45	2.18	47.10	1.9	0.17	0.0011	0.63	0.37
<2.0–3.0)	23.0 ±0.09	2.24	25.16	0.49	0.54	52.55	→∞	0.25	−0.0027	0.71	0.28
<1.0–2.0)	18.1 ±0.12	4.52	28.80	1.12	0.55	32.95	→∞	0.22	−0.0028	0.62	0.40
<0.5–1.0)	5.2 ±0.06	7.97	38.85	0.38	0.12	24.68	1.6	0.18	0.0009	0.40	0.59
<0.25–0.5)	5.7 ±0.09	8.25	36.84	1.02	0.41	28.60	1.3	0.22	0.0030	0.54	0.46
<0.25	2.6 ±0.04	0.58	6.55	0.09	0.05	38.14	→∞	0.22	0.0010	0.68	0.31

Explanations: *Phi* = variogram range (distance at which theoretical variogram curve reaches its maximum as the range); Pr_Range = practicle range (value at which variogram reaches 95% of the asymptote); *Sill* = difference between the asymptote and the nugget; nugget = intercept of the variogram model curve; *SDL* = nugget to sill ratio as an indicator of spatial autocorrelation strength; Kappa = Matern model smoothing parameter; regression R_{adj}^2 = adjusted R^2 of the regression model with terrain and tree stand variables as predictors; *NRMSE* = normalised root mean squared error; *MSDR* = mean squared deviation ratio.
Source: own study.



>10 mm
7–10 mm
5–7 mm
3–5 mm
2–3 mm
1–2 mm
0.5–1 mm
0.25–0.5 mm
< 0.25 mm

Fig. 2. Spatial variation of aggregate fractions (in mm); source: own study

Table 2. Descriptive statistics of the organic matter content, particle size distribution, pH, and the ion composition of the soil water extract (N = 105)

Property	Mean ±standard error	Minimum	Maximum	Standard deviation
Organic matter content				
Organic matter (%)	0.60 ±0.015	0.22	1.48	0.20
pH and ion composition of the soil water extract				
pH	7.16 ±0.019	6.50	7.80	0.25
Cl^+ ($meq\cdot dm^{-3}$)	0.39 ±0.007	0.19	0.76	0.09
SO_4^{2+} ($meq\cdot dm^{-3}$)	0.42 ±0.008	0.23	0.73	0.10
Ca^{2+} ($meq\cdot dm^{-3}$)	0.49 ±0.008	0.34	1.16	0.10
Mg^{2+} ($meq\cdot dm^{-3}$)	0.26 ±0.011	0.00	0.72	0.14
HCO_3^+ ($meq\cdot dm^{-3}$)	1.36 ±0.019	0.89	2.38	0.25
Ka^++Na^+ ($meq\cdot dm^{-3}$)	1.42 ±0.026	0.36	2.52	0.33
Carbonate content an particle size distribution (according Katschinski)				
Carbonate content (%)	22.86 ±1.43	11.40	47.30	9.52
Medium and coarse sand (1.00–0.25 mm)	1.68 ±0.25	0.21	6.18	1.67
Fine sand (0.25–0.05 mm)	17.22 ±2.00	0.06	62.84	13.27
Coarse silt (0.05–0.01 mm)	15.54 ±1.62	4.12	37.08	10.74
Medium silt (0.01–0.005 mm)	7.68 ±0.80	0.00	24.72	5.28
Fine silt (0.005–0.001 mm)	4.88 ±0.32	0.21	8.24	2.15
Clay (<0.001 mm)	53.00 ±2.31	18.62	86.52	15.29
Physical clay (<0.01 mm)	65.56 ±2.46	26.86	95.00	16.31

Source: own study.

about the spatial distribution of the molluscs allows us to obtain the partial distribution of ecogeographical variables in places where molluscs are found. Mollusc microhabitat preferences may be quantified by comparing the global and partial distributions. Obviously, the fact that global and partial distributions do not converge indicates the structural role of the corresponding variable in determining the form of the ecological niche (Fig. 3).

The assessment of the ecological niche parameters can be obtained using the ENFA approach. The ENFA approach is allowed to identify the marginality axis and the specialisation axis of the ecological niche of *V. pulchella* using the aggregate fractions of the soil as the predictors (Fig. 4).

The test for the statistical significance has shown that the eigenvalues of the marginality axis of the ecological niche of the

Table 3. Profile distribution of physical properties of technosol

Layer (cm)	Water content (%)	Bulk density ($g \cdot cm^{-3}$)	Solid phase density ($g \cdot cm^{-3}$)	Porosity (%)
	mean ±standard error			
0–10	15.34 ±0.13	1.20 ±0.14	2.53 ±0.15	52.57 ±0.14
10–20	16.51 ±0.16	1.23 ±0.19	2.54 ±0.11	51.57 ±0.19
20–30	17.50 ±0.15	1.24 ±0.07	2.54 ±0.03	51.18 ±0.20
30–40	24.76 ±0.10	1.12 ±0.05	2.54 ±0.10	55.91 ±0.19
40–50	25.97 ±0.15	1.14 ±0.09	2.54 ±0.15	55.12 ±0.23
50–60	25.30 ±0.12	1.15 ±0.10	2.55 ±0.16	54.90 ±0.27
60–70	25.30 ±0.20	1.16 ±0.09	2.55 ±0.09	54.51 ±0.10
70–80	19.04 ±0.19	1.15 ±0.19	2.55 ±0.05	54.90 ±0.17
80–90	21.57 ±0.16	1.27 ±0.16	2.55 ±0.16	50.20 ±0.12
90–100	23.67 ±0.14	1.29 ±0.13	2.56 ±0.13	49.61 ±0.10

Source: own study.

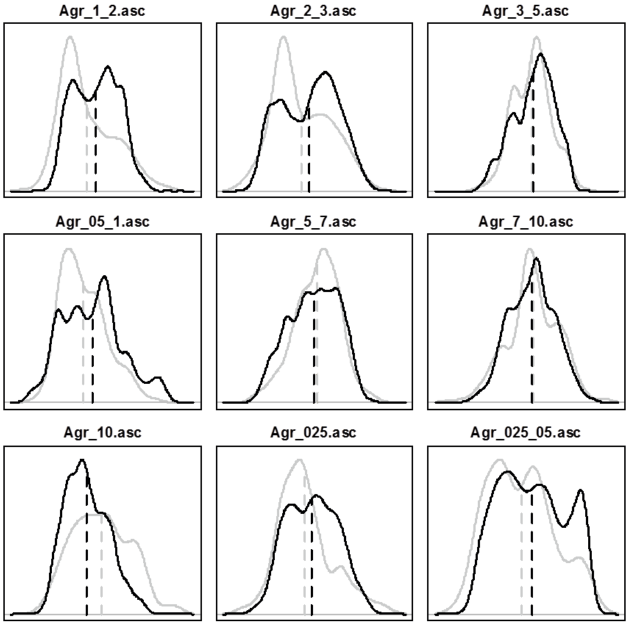


Fig. 3. The total distribution of the aggregate fractions (in mm) on the area (black lines) and the partial distribution of aggregate fractions in points where *Vallonia pulchella* were detected (grey lines); source: own study

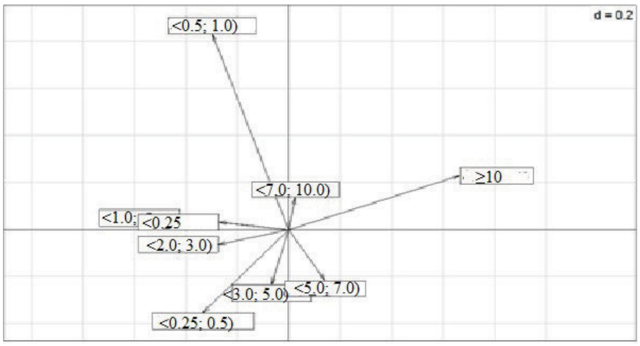


Fig. 4. Correlation between aggregate fractions (in mm) and axes selected as a result of ENFA analysis: *X*-axis corresponds to marginality and *Y*-axis specialisation; source: own study

V. pulchella (γ_{marg} = 0.98, $p < 0.001$) and the axis of the specialisation (γ_{spec1} = 1.94, $p < 0.03$) significantly differ from the eigenvalues obtained as the result of a similar statistical procedure for random alternatives. The results of the ENFA approach may suggest that the marginality of the *V. pulchella* ecological niche is closely related to the variability of the aggregate structure: molluscs prefer areas where the content of aggregates of 5.0–7.0 to 10.0 mm prevails, and they avoid areas where the content of small aggregates increases.

The ecological niche can be presented by integral variables such as the axis of marginality and specialisation, which are the basis to build the spatial variation map for the habitat suitability index (*HSI*) (Fig. 5).

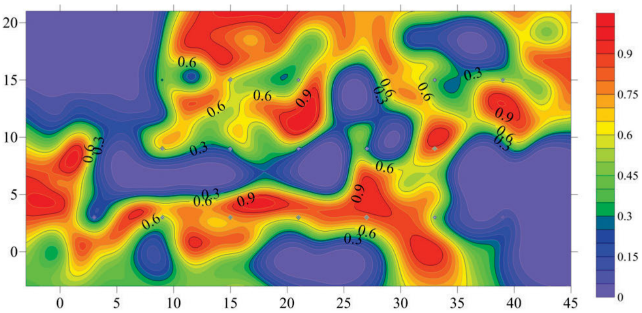


Fig. 5. Spatial distribution of the habitat suitability index (*HSI*) for *Vallonia pulchella* within the experimental site on green-grey clays based on ENFA: on the abscissa and ordinate axis – local polygon coordinates (m), scale – habitat suitability index (0–100%); source: own study

The axes of the marginality and the specialisation of the ecological niche correlate with the edaphic factors and the phytoindication scales (Tab. 4). The marginality of the *V. pulchella* ecological niche correlates with indicators of the soil impedance at depths from 0–5 to 20–25 cm. It is also worth noting that the axis of marginality correlates with the variability scale for variability of damping (*fH*), acidity (*Rc*), aeration (*Ae*), and humidity (*Om*). The specialisation correlates with the soil penetration resistance at the depth of 25–35 cm, nitrogen content in the soil, and acidity regime of the soil.

Table 4. The correlation of marginality (Mar) and specialisation (Spel) with environmental variables

Environmental variables	Mar	Spel
Electrical conductivity ($dS \cdot m^{-1}$)	0.34	0.19
Soil penetration resistance in MPa at depth (cm)		
0–5	−0.33	–
5–10	0.34	–
10–15	0.26	–
15–20	0.38	–
20–25	0.34	–
25–30	–	0.20
30–35	–	0.27
35–40	–	–
40–45	–	–
45–50	–	–

cont. Tab. 4

Environmental variables	Mar	Spel
Didukh phytoindicator values		
Hd	–	–
fH	0.30	–
Rc	–0.31	–0.44
Sl	–	–
Ca	–	–
Nt	–	0.29
Ae	0.28	–
Tm	–	–
Om	0.23	–
Kn	–	–
Cr	–	–
Lc	–	–

[1)] Only correlation coefficients are shown that are significant for $p < 0.05$.
Explanations: *Hd* = soil humidity, *fH* = variability of damping, *Rc* = soil acidity, *Sl* = total salt regime, *Ca* = carbonate content in soil, *Nt* = nitrogen content in soil, *Ae* = soil aeration, *Tm* = thermal climate, *Om* = humidity, *Kn* = continental climate, *Cr* = cryoclimate, *Lc* = light regime.
Source: own study.

DISCUSSION

The aggregate composition corresponds to the relative content of aggregates of different sizes in soil. The aggregate structure is an informative indicator denoting the spatial variability of technosols properties. In various soils, aggregates differ in size and shape. The stability of aggregates reduces the loss of soil, carbon, nitrogen, and phosphorus [Kasper *et al.* 2009], and it increases the number of macro aggregates. We found that mesoaggregates, namely the aggregates of 1.0–5.0 mm in size, dominate in the studied area. This suggests that organic matter plays a considerable role in the mesoaggregates formation because the organic substance promotes soil aggregation [Duchicela *et al.* 2013]. The increase in the organic matter content promotes an increase in the proportion of mesoaggragates due to microaggragates [Oades 1993].

In the conditions of the polygon examined, it was found that aggregate fractions are characterised by their spatial variability pattern. Thus, spatial patterns should be noted to be significantly different for aggregate fractions of various sizes. This may indicate different mechanisms behind the formation of soil aggregates of different sizes. Experimentally determined values of practical ranges exceed the distance between sampling points, which indicates that the selected sampling strategy allows to assess the spatial variability of the aggregate soil structure.

For the studied aggregate fractions, it is impossible to find a universal model to describe the spatial variation from among the traditional ones. Therefore, the Matérn model is the most suitable model to study features of aggregate fractions spatial patterns. A significant difference in geostatistics, which describes the spatial variation of aggregate fractions, indicate a significant heterogeneity of processes that result in the formation of aggregates. Accordingly, these processes may lead to a significant diversity of ecological regimes, which have a direct impact on micromolluscs. We established that aggregate fractions are valuable predictors that can explain ecological niche marginality and specialisation of *V. pulchella*. This is quite consistent due to the proportional heterogeneity of the soil which is induced by aggregate fractions and the size of micromolluscs. The specificity of water and air regimes is determined by the ratio of aggregate fractions, which explains the effect on micromolluscs.

Another important result is that the axes of marginality and specialisation for the micromolluscs ecological niche correlate with ecosystem properties that are at another spatial scale level. The mechanical impedance of the soil was measured at the depth where molluscs are unlikely to be found due to unfavourable living conditions. Vegetation was described per squares of 3 × 3 m, which significantly exceeded the size of a soil sample of 10 g, in which micromolluscs were found. However, there is a link between these ecosystem scales. The reason for this is that soil properties and features of the vegetation cover affect the aggregate structure of soil, and the structure determines living conditions for molluscs.

The distribution of micromolluscs is uneven and it is explained by the variability of the natural environment characteristics. It contributes to the structural and the functional diversity [Brind'Amour *et al.* 2011]. Aggregates of various sizes have been affected by *V. pulchella,* i.e. macro-aggregates of large porosity. This is important for the penetration of water and air, and for the development of microbes, small animals, and roots of plants. This is a necessary condition to support molluscs, their breathing, movement, and consumption of nutrients. Small aggregates form a small pore system that adversely affects the life of micromolluscs. Thus, soil aggregates of various sizes cause dynamic changes in the spatial distribution of *V. pulchella.* It can play an important role in the breadth of the soil biodiversity and its functioning.

Our study focused on the spatial variation of molluscs and soil properties. Of course, the abundance of molluscs and the influence of environmental factors on them varies throughout the season. The studying of spatial and temporal dynamics of mollusc populations will dealt with in our future studies. It is also an important aspect of further research into unit resistance and importance of this property as a factor that affects micromolluscs.

CONCLUSIONS

The aggregate structure of soil is one of the main conditions that determines the temporal dynamics of the terrestrial invertebrate community. The study revealed that soil aggregates play an important role in the structuring of the *V. pulchella* ecological niche. The sensitivity of micromolluscs to environmental factors changes in space. The content of agronomically valuable aggregates has a positive effect on the abundance of micromolluscs. The marginality of the ecological micromollusc niche of is correlated with soil humidity, high soil aeration, and soil acidity (according Didukh). Moreover, *V. pulchella* avoids areas of high electrical conductivity and an increased soil penetration resistance. Soil aggregates have a great ecological importance for soil biodiversity, but many other aspects of these relationships require detailed studies.

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