# ECOLOGICAL IMPORTANCE OF SPATIAL VARIABILITY OF SOIL PENERATION RESISTANCE IN NATURAL FARMING FIELD

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The aim of the investigation is assessment of the spatial organization of the ordinary chernozem when using technology of natural agriculture according to data of the soil penetration resistance. We set the following tasks: to investigate penetration resistance of the ordinary chernozem on the fields processed according to technologies of traditional and natural agriculture; to classify a surface of fields on penetration resistance; to define dynamics of biological efficiency of the studied fields by the NDVI; to construct digital elevation model; to find out dependence between penetration resistance of the soil, a relief and biological efficiency of the studied fields. It is established that average values of penetration resistance of the soil of fields naturally raise with depth from 1,96 MPas in the top 15-centimetric layer to 4,02 MPas on depth 45-50 cm. Results of the cluster analysis allowed to allocate four clusters. In space each cluster is presented by a quantity of accurately isolated pathches (pedons), homogeneous for values of penetration resistance on a profile. The main difference between clusters is intensity from which penetration resistance with depth increases. The horizons which regularly are exposed to plowing (0-25 cm), at the end of a vegetative season are characterized by the penetration resistance which variability in space is caused by geomorphological determinants. Regular plowing leads to evenness of the mechanical properties of the soil. In the under plowing horizon the pedon structure of the soil has enough time for restoration after the next deep plowing therefore on depth of 35-50 cm spatial structures in the size of 45-100 m in diameter are observed. It is established that the allocated clusters determine productivity of an agroecosystem owing to features of profile change of penetration resistance of the soil. Optimum conditions for efficiency are formed within a cluster 1. The worst conditions for primary production are found for a cluster 2; clusters 3 and 4 are intermediate on NDVI value. The cluster 1 in the territory is presented by fragmentary loci – maximum on the area from which makes 37,79 % from the territory which occupies a cluster. The cluster 2 represents almost solid formation – 90,37 % from the area of a cluster are occupied by the biggest locus. Similar indicators for clusters 3 and 4 make 44,28 and 63,78 % respectively. Continuous character of an arrangement of a cluster 2 within which adverse conditions for cultivation of cultures on penetration resistance were created, assumes possibility of local carrying out deep plowing for optimization of physical properties of the soil.

Keywords: soil penetration resistance, normalized difference vegetation index, cluster analysis, natural agriculture.

The technology of natural agroproduction consists in complete refusal of application of genetically modified organism, antibiotics, pesticides and mineral fertilizers. It leads to increase of natural biological activity in the soil, to restoration of balance of nutrients, strengthening of regenerative properties of the soil, normalization of function of soil organisms. There is a humus gain and as result increase in crops productivity. Result of natural agriculture is ecologically safe production, free from chemical elements unusual for food [1].

The idea of natural agriculture is at present popular in many countries of the world, especially in Europe. Ukraine possesses an extreme reserve of fertile soils therefore in the past it was and in the future should be one of world leaders of production of high-quality, non-polluting food [2]. But full information on a condition of soils, their fertility and physical properties is for this purpose necessary.

As the indicator of soil properties doubtless advantage has an indicator of its mechanical resistance [3]. It is necessary to carry a high informative and productivity, relative simplicity and high precision of measurement to such advantages. Mechanical resistance is an irreplaceable indicator for an assessment of conditions of germination of seeds and their development at the first stages ontogenesis, including estimates of ability of root hairs to master not only inter- but also intraaggregate space [4, 5]. That is, by means of an indicator of mechanical resistance it is possible to estimate not only durability of the soil unit, but also quality of its composition. And such assessment cannot be received using a traditional indicator of density of soil composition [3].

Proceeding from the aforesaid, definition of the spatial organization of the ordinary chernozem when using technology of natural agriculture according to mechanical resistance of the soil was the purpose of our research.

For achievement of the purpose the following tasks were put:

• to investigate mechanical resistance of the ordinary chernozem on the fields processed according to technologies of traditional and natural agriculture;

• to classify the obtained data on mechanical resistance;

• to define size of biological efficiency of the studied fields by the Normalized Difference Vegetation Index (NDVI) received by the analysis of remote space images;

• to construct the digital elevation model received by the analysis of remote space images;

• to find out dependence between mechanical resistance of the soil, a relief and biological efficiency of the studied fields.

**Materials and methods of researches**

Researches are carried out in 2012. Two adjacent fields are located at distance of 5 km on the North from by Sinelnikovo (The Dnepropetrovsk region). On one field (east part of the investigated territory) since 2008 in practice of agricultural production refused application of pesticides and mineral fertilizers. Fight against weeds on this field is conducted by means of manual weeding. Such system of agriculture can be carried to so-called natural agriculture. The next field is cultivated on intensive technology with application of pesticides and mineral fertilizers. On both fields in 2012 the seed sunflower was cultivated.

On September 25 and on October 2 field researches were carried out. Mechanical resistance and a soil electrical conductivity (on October 2) was measured in 90 points in the field of natural agriculture (on September 25) and in 92 points in the field of intensive agriculture, and also soil samples from the top 10-cm of the horizon are collected. Points are located in the form of 6 transects on 15 points in everyone (in the field of intensive agriculture the first two transects are presented by 16 points). Roughly, the distance between points in transect made 75 m. Exact coordinates of example places were fixed about the help of the GPS navigator. The distance between transects in the field of natural agriculture roughly made 50–70 m.

Measurement of mechanical resistance of soils were made in field conditions by means of manual hand penetrometer Eijkelkamp on depth to 50 cm with an interval 5 cm. The average error of results of measurements of the device makes ±8 %. Measurements were made by a cone with the extent of cross-section section of 2 $cm^2$. Within each point of measurement of mechanical resistance of the soil were made in single frequency.

In work the analysis of the Landsat remote images made on April 16, on May 2 and 11, on June 12 and 19, on July 14 and 30 and on August 6 and 22, 2012 is carried out. Thus, the time span of images covers the main part of the vegetative period. Images are received from the Earthexplorer server (http://earthexplorer.usgs.gov/).

**Results of researches and their discussion**

Mechanical resistance of the soil on two fields does not differ statistically significantly therefore we gave generalized results on all territory (tab. 1).

Mechanical resistance of the soil to the horizon of 15 cm significantly does not differ between the next horizons and makes 1,96–1,99 MPa. Obviously, such result grows out of plowing of the farmland. Since the horizon of 15-20 cm, and further, the gradual increase in mechanical resistance of the soil from 2,18 MPa on depth of 15-20 cm to 4,02 MPa on depth 45–50 cm is observed.

The factor of a variation of mechanical resistance of the soil gradually decreases from a surface to depth of 25-30 cm then the local maximum of variability on depth 35–40 cm is observed. If for a critical mark to take mechanical resistance of the soil in 3 MPa, i.e. such mechanical resistance which roots of plants unable to overcome at the growth, it is possible to note that in not less than 95 % of cases this boundary is not overcome up to depth 30–35 cm. After the specified depth critical value of mechanical resistance is in 95 % a confidential interval.

*Table 1*

**Mechanical resistance of the soil on various depths (in MPa)**

| Depth, cm | N | Mean | The confidential limits | | Minimum | Maximum | CV, % | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|---|
| | | | – 95 % | +95 % | | | | | |
| 0–5 | 182 | 1,96 | 1,86 | 2,07 | 0,60 | 4,20 | 37,59 | 0,24 | – 0,44 |
| 5–10 | 182 | 1,99 | 1,89 | 2,10 | 0,60 | 4,50 | 35,36 | 0,77 | 0,85 |
| 10–15 | 182 | 1,96 | 1,88 | 2,05 | 0,60 | 4,50 | 30,69 | 0,86 | 1,29 |
| 15–20 | 182 | 2,18 | 2,09 | 2,27 | 0,70 | 5,00 | 29,01 | 0,88 | 2,03 |
| 20–25 | 182 | 2,36 | 2,27 | 2,45 | 1,00 | 4,80 | 25,70 | 1,05 | 2,37 |
| 25–30 | 182 | 2,56 | 2,48 | 2,65 | 1,20 | 5,00 | 22,80 | 0,99 | 1,53 |
| 30–35 | 182 | 2,81 | 2,70 | 2,92 | 1,50 | 5,00 | 26,21 | 1,10 | 0,92 |
| 35–40 | 182 | 3,17 | 3,05 | 3,30 | 1,70 | 5,00 | 27,61 | 0,73 | – 0,43 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 40–45 | 182 | 3,55 | 3,41 | 3,68 | 1,70 | 5,00 | 26,35 | 0,31 | – 1,08 |
| 45–50 | 182 | 4,02 | 3,89 | 4,14 | 1,90 | 5,00 | 21,32 | – 0,34 | – 0,93 |

Attempt to describe variability of mechanical resistance in terms of geomorphological predictors by means of linear regression did not give satisfactory results: the model described variation is in limits of 8-11 % (fig. 1).

Regression application on a method of support vectors (a function kernel – ANOVA RBF) considerably improved predictive possibilities of model to 37–58 %. Thus, it is possible to argue that spatial variability of mechanical resistance of the soil is in dependence from a geomorphological situation, but nature of this connection is beyond the linear description.

Despite distinctions in absolute values of descriptive abilities of regression models, the tendency of variability of the described variation both at linear model, and on a method of support vectors, is similar: a complex of geomorphological characteristics effect on mechanical resistance on depth 5–10 and 10–15 cm. The second maximum of values of the described dispersion is observed for depth 40–45 and 45–50 cm. Remarkably that the horizons which regularly are exposed to plowing, at the end of a vegetative season are characterized by the mechanical resistance which variability in space is caused by geomorphological determinants. It is obvious that water and thermal dynamics forced by relief is reflected in spatial variability of the soil. So, Mantel's test between matrixes of distances of Makhalanobis on mechanical resistance and on geomorphological indicators, is equal 0,17 ($R$ = 0,001). The partial test between the same matrixes with a matrix of geographical distances as a controlling variable is equal 0,16 ($R$ = 0,002). It testifies about volume, geomorphological determinants influence mechanical resistance of the soil, passing other factors of the geographical nature.

Geostatistical characteristics of mechanical resistance of the soil on various depths are presented in table 2.

*Table 2*

**Geostatistical characteristics of mechanical resistance of the soil**

| **Depth, cm** | **Nagget** | **Partial sill** | **Length, m** | **100-SDL, %** | $R^2$ |
|---|---|---|---|---|---|
| 0–5 | 0,26 | 0,31 | 388,8 | 54,39 | 0,10 |
| 5–10 | 0,16 | 0,32 | 353,7 | 66,67 | 0,07 |
| 10–15 | 0,15 | 0,24 | 451,2 | 61,54 | 0,08 |
| 15–20 | 0,09 | 0,31 | 145,4 | 77,50 | 0,07 |
| 20–25 | 0,01 | 0,37 | 144,9 | 97,37 | 0,04 |
| 25–30 | 0,01 | 0,35 | 114,9 | 97,22 | 0,05 |
| 30–35 | 0,00 | 0,55 | 90,2 | 100,00 | 0,05 |
| 35–40 | 0,03 | 0,76 | 42,7 | 96,20 | 0,07 |
| 40–45 | 0,12 | 0,8 | 47,7 | 86,96 | 0,06 |
| 45–50 | 0,35 | 0,44 | 45,3 | 55,70 | 0,07 |

The trend extracted by means of a third degree polynomial:

$$\Omega_{xy} = a_1x + a_2y + a_3x^2 + a_4y^2 + a_5x^3 + a_6y^3 + a_7xy + a_8x^2y + a_9xy^2,$$

where $x$ and $y$ – geographical coordinates; $\Omega_{xy}$ – mechanical resistance of the soil in a point with coordinates $x$ and $y$; $a_1 \ldots a_9$ – regression coefficients.

As appears from the data provided in the table, mechanical resistance of the soil on various depths within studied fields, practically is not subject to a spatial trend. The part of the variation described by regression model, is at level of 5-10 % that is obvious not enough to recognize a role of a trend essential. Nevertheless, at variability of mechanical resistance of the soil is present spatial a component which is caused by local autocorrelation. To it testifies rather high indexes 100-SDL according to which, the share spatial variability components for mechanical resistance of the soil makes 54,39–100,00 %. It should be noted that the role of autocorrelation increases with increase in depth, reaching a maximum in the horizon 20–40 cm. At further increase the indicator 100-SDL decreases a little.

The autocorrelation radius is characterized by the general tendency to reduction with increase in depth. On depth of 0-15 cm this indicator is at level of 353,7-451,2 m. Since depth of 15 cm, the influence radius sharply decreases and makes 42,7–47,7 m on depth 35–50 cm. Obviously, regular plowing levels mechanical properties of the soil owing to what local spatial formations of pedon level collapse, and structural levels pedon-polipedon unite in one. In the under plowing horizon the pedon structure of the soil has enough time for restoration after the next deep plowing therefore on depth of 35-50 cm spatial structures of dimension of 45-100 m are observed.

Allocation spatial homogeneous sites of the soil on mechanical resistance was the following task. For this purpose results of our researches were processed by means of the cluster analysis. The cluster analysis is widely applied statistical procedure for classification of data. Two characteristics define results of the cluster analysis such as a measure of similarity/distinction between objects which are classified also a way of formation of clusters.

As measures of similarity the Minkovsky, Chebyshev, Manhattan, Euclidian distance, Pearson correlation and correlation indexes etc. can act.

Among methods of a clustering it is necessary to specify a method of the near neighbor, the distant neighbor, a centroid clustering, a median clustering, Ward's method etc.

Application of various approaches of the cluster analysis is defined by the nature of studied object, adequacy of the concept of methods to properties of object. Possibility of substantial interpretation of results of a clustering is very important.

For allocation of rather homogeneous territorial units on the basis of mechanical resistance of the soil as criterion of uniformity it is possible to choose coherence and synchronism of variability of indicators of mechanical resistance on a soil profile that can be reflected by means of Pearson correlation coefficient. The Pearson correlation coefficient is a suitable indicator of similarity of profiles. Formally the profile is defined as a vector of values of the object, graphically represented in the form of the broken line.

Kronbakh and Glezer (1953) for the first time showed that similarity between profiles is defined by the following three elements:

– a form, i.e. descents and liftings for the broken line for all variables;

– dispersion, i.e. dispersion of values of a variable for object on all variables concerning their average;

– a raising (level or shift), i.e. average value for object on all variables.

Sensitivity Pearson correlation coefficient only to a form means that two profiles can have correlation +1,0, and still not to be identical (i.e. profiles of objects do not pass through the same points). The Pearson correlation coefficient is sensitive only to a form because of an implicit standardize value of each object on all variables.

Results of the cluster analysis of sites on mechanical resistance are given on fig. 2. As the cluster decision we chose option with 4 clusters. It should be noted that hierarchical cluster procedure assumes allocation possibility from 2 to *N-1* clusters, where *N* – sample volume. There are procedures which allow to stop by some criterion on some intermediate version of the cluster decision. After all it is obvious that "too small" number of clusters gives us the volume groups which structure is artificially expanded. "Too big" number of clusters does not solve the main problem of classification – receiving foreseeable quantity of rather homogeneous objects as instead of initial number of objects we receive a new set, slightly smaller on volume, but all the same considerable for understanding of their nature.

As a cluster in ecological researches should act real group of objects which are characterized by a certain uniformity of statistical parameters, and also uniformity of connection with other phenomena and processes of their ecological environment. If statistical uniformity is a criterion which logically follows from properties of the cluster analysis, sometimes between various cluster decisions there is no accurate distinction on degree of uniformity or other statistical properties. Therefore as solving criterion we chose step-type behavior of clusters in relation to external characteristics of an agroecosystem.

So, the decision from 4 clusters is characterized by significant distinction between clusters of values of such geomorphological indicators, as a slope, a relief roughness, curvature in the plan and an erosion factor, and also vegetative indexes for the different periods (tab. 3).

*Table 3*

**The analysis of variance of mechanical resistance cluster of and vegetative indexes and topographical characteristics**

| Indicators | SS | df | MS | SS | df | MS | *F*-value | *p*-level |
|---|---|---|---|---|---|---|---|---|
| **NDVI** | | | | | | | | |
| On April 16 | 0,00 | 3 | 0,00 | 0,13 | 178 | 0,00 | 1,20 | 0,31 |
| On May 2 | 0,00 | 3 | 0,00 | 0,27 | 178 | 0,00 | 0,98 | 0,40 |
| **On May 11** | **0,01** | **3** | **0,00** | **0,12** | **178** | **0,00** | **2,60** | **0,05** |
| **On June 12** | **0,01** | **3** | **0,00** | **0,21** | **178** | **0,00** | **2,61** | **0,05** |
| On June 19 | 0,01 | 3 | 0,00 | 0,34 | 178 | 0,00 | 1,11 | 0,35 |
| On July 14 | 0,05 | 3 | 0,02 | 1,13 | 178 | 0,01 | 2,44 | 0,07 |
| **On July 30** | **0,07** | **3** | **0,02** | **1,19** | **178** | **0,01** | **3,52** | **0,02** |
| **On August 6** | **0,08** | **3** | **0,03** | **0,61** | **178** | **0,00** | **7,91** | **0,00** |
| **On August 22** | **0,08** | **3** | **0,03** | **0,80** | **178** | **0,00** | **6,28** | **0,00** |
| **Geomorphological indicators** | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Dem, m | 32,57 | 3 | 10,86 | 1996,06 | 178 | 11,21 | 0,97 | 0,41 |
| Twi_saga | 5,50 | 3 | 1,83 | 156,40 | 178 | 0,88 | 2,09 | 0,10 |
| TWI | 7,99 | 3 | 2,66 | 274,03 | 178 | 1,54 | 1,73 | 0,16 |
| **Slope, °** | **0,00** | **3** | **0,00** | **0,00** | **178** | **0,00** | **2,75** | **0,04** |
| **Ruggedness, m** | **0,08** | **3** | **0,03** | **1,70** | **178** | **0,01** | **2,87** | **0,04** |
| Prof_curv*10-31/m | 0,00 | 3 | 0,00 | 0,00 | 178 | 0,00 | 0,57 | 0,64 |
| **Plan_curv*10-31/m** | **0,00** | **3** | **0,00** | **0,00** | **178** | **0,00** | **2,97** | **0,03** |
| Mass_balance | 0,00 | 3 | 0,00 | 0,03 | 178 | 0,00 | 0,89 | 0,45 |
| **Ls_factor** | **0,02** | **3** | **0,01** | **0,30** | **178** | **0,00** | **3,40** | **0,02** |
| Hillshad | 0,00 | 3 | 0,00 | 0,13 | 178 | 0,00 | 2,26 | 0,08 |
| Direct_insol | 0,00 | 3 | 0,00 | 0,10 | 178 | 0,00 | 1,63 | 0,18 |
| Diffuse_insol | 0,00 | 3 | 0,00 | 0,00 | 178 | 0,00 | 0,97 | 0,41 |
| Mrrtf | 5,93 | 3 | 1,98 | 161,00 | 178 | 0,90 | 2,18 | 0,09 |
| Mrvbf | 0,73 | 3 | 0,24 | 173,06 | 178 | 0,97 | 0,25 | 0,86 |
| Wind | 0,00 | 3 | 0,00 | 0,06 | 178 | 0,00 | 0,24 | 0,87 |
| Altitude | 91,88 | 3 | 30,63 | 4748,90 | 178 | 26,68 | 1,15 | 0,33 |

***Symbols:*** see tab. 1; SS – the sum of squares; df – freedom degrees; MS – an average square of effect

It should be noted that the cluster decisions received on the basis of measures sensitive not to a variability form on a profile as Pearson correlation coefficient and to absolute values as, for example, Euclidian metrics, did not give clusters which were characterized by such specificity concerning external characteristics in relation to mechanical resistance of the soil. Thus, it is possible to argue that absolute value of mechanical resistance of the soil is not determined by geomorphological factors but the profile distribution of this index is determined. It is obvious that on dynamics of absolute value of mechanical resistance of the soil crucial importance renders a humidity mode. And nature of profile distribution of mechanical resistance reflects local features of soil forming process which are under the influence of such important soil formation factor as a relief.

It is possible to assume that the allocated clusters determine efficiency of an agroecosystem owing to features of profile change of mechanical resistance of the soil.

The assessment of a land biomass is necessary for studying of efficiency, a circulation of carbon, distribution of nutrients in land ecosystems (Ryu et al., 2004). Methods of the analysis of data of remote sensing of the earth allow to estimate properties and processes in ecosystems and their year dynamics at various large-scale levels as supervision from the satellite are carried out with considerable spatial coverage, high spatial resolution and temporary periodicity (Running et al., 2000). In a number of researches it is shown that such indexes as a spectral vegetative index (SVI), the simple relation (SR), the normalized differential vegetative index (NDVI) and the corrected normalized differential vegetative index ($NDVI_c$), received by means of data from the satellite, are good predictors of an index of a leaf surface (LAI), a biomass and efficiency of wood and meadow ecosystems (Fassnacht et al., 1997; Jakubauskas, 1996; Nemani et al., 1993; Paruelo, Lauenroth, 1998; Steininger, 2000; Tieszen et al., 1997). The analysis of received information consists of two stages – statistical and geostatistical.

The statistical approach allows to compare variability of an index of NDVI in time, considering two fields as complete objects. The data presented in fig. 3 testify that two fields are characterized by similar dynamics of vegetation during the vegetative period. It is established that active development of vegetative weight of culture is observed since the end of May. This growth lasts up to the middle of July. Then the plateau which comes to an end with decrease in an index of NDVI since the beginning of August is observed.

The analysis of variance showed (tab. 4) that between NDVI values on two fields is observed statistically significant distinctions. Stable prevalence of an index of NDVI in the field with natural technology of agriculture in comparison with a field intensive technology is observed from the middle of July.

*Table 4*

**The analysis of variance of a vegetative index of NDVI between fields with various technologies of agriculture**

| Date | SS-effect | df-effect | MS-effect | SS - Error | df - Error | MS - Error | F-value | p-level |
|---|---|---|---|---|---|---|---|---|
| **On April 16** | 0,00 | 1 | 0,00 | 0,13 | 180 | 0,00 | 0,30 | 0,58 |
| **On May 2** | 0,05 | 1 | 0,05 | 0,23 | 180 | 0,00 | 39,59 | 0,00 |
| **On May 11** | 0,00 | 1 | 0,00 | 0,12 | 180 | 0,00 | 0,38 | 0,54 |
| **On June 12** | 0,01 | 1 | 0,01 | 0,21 | 180 | 0,00 | 6,89 | 0,01 |
| **On June 19** | 0,00 | 1 | 0,00 | 0,35 | 180 | 0,00 | 0,04 | 0,84 |
| **On July 14** | 0,07 | 1 | 0,07 | 1,10 | 180 | 0,01 | 11,52 | 0,00 |
| **On July 30** | 0,08 | 1 | 0,08 | 1,18 | 180 | 0,01 | 12,69 | 0,00 |
| **On August 6** | 0,07 | 1 | 0,07 | 0,62 | 180 | 0,00 | 19,36 | 0,00 |
| **On August 22** | 0,20 | 1 | 0,20 | 0,69 | 180 | 0,00 | 52,02 | 0,00 |

The geostatistical analysis allows to compare features of spatial distribution of an index of NDVI within each of compared fields.

Such geostatistical procedure as kriging should be carried out for spatial and stationary process. Therefore initially from observable data the spatial trend should be taken. It can be made by means of the regression analysis if as predictors to use spatial coordinates of objects. A trend was extracted by means of third degree polynomial:

$$NDVI_{xy} = a_1x + a_2y + a_3x^2 + a_4y^2 + a_5x^3 + a_6y^3 + a_7xy + a_8x^2y + a_9xy^2,$$

where $x$ and $y$ – geographical coordinates; $NDVI_{xy}$ – values of an index *of NDVI* in a point with coordinates $x$ and $y$; $a_1 \dots a_9$ – regression factors. The regression model residuals is deprived of a third degree trend and can be considered as stationary spatial process.

The part of the variation described by regression model of dependence of a variable from spatial coordinates (a trend, in our case of third order degree) – $R^2$ gives important information on the nature of studied process. This value shows the level of a spatial trend in variability of an index of NDVI. The trend in a general view describes a complex of the factors which action is continuous within all studied territory.

The analysis of the received data testifies that the role of a trend amplifies together with increase in the total phytomass on fields (tab. 5).

*Table 5*

**Geostatistical characteristics of an index of NDVI during the various moments vegetative period**

| Date | Agriculture type | Nagget * $10^4$ | Threshold * $10^4$ | Radius, m | 100-SDL, % | $R^2$ |
|---|---|---|---|---|---|---|
| **On April 16** | The natural | 1,87 | 7,30 | 104,39 | 79,61 | 0,22 |
| | The intensive | 3,75 | 2,17 | 153,80 | 36,66 | 0,28 |
| **On May 2** | The natural | 11,40 | 21,03 | 153,21 | 64,85 | 0,63 |
| | The intensive | 17,06 | 27,82 | 166,72 | 61,99 | 0,37 |
| **On May 11** | The natural | 4,44 | 32,34 | 87,69 | 87,92 | 0,45 |
| | The intensive | 11,40 | 29,27 | 148,18 | 71,97 | 0,50 |
| **On June 12** | The natural | 32,27 | 74,20 | 317,14 | 69,69 | 0,61 |
| | The intensive | 12,20 | 28,09 | 176,93 | 69,71 | 0,39 |
| **On June 19** | The natural | 6,83 | 45,41 | 183,87 | 86,93 | 0,57 |
| | The intensive | 5,58 | 12,08 | 185,01 | 68,42 | 0,56 |
| **On July 14** | The natural | 0,00 | 19,18 | 143,73 | 100,00 | 0,72 |
| | The intensive | 2,14 | 14,91 | 171,44 | 87,46 | 0,76 |
| **On July 30** | The natural | 1,31 | 31,61 | 149,66 | 96,03 | 0,71 |
| | The intensive | 1,25 | 9,29 | 182,36 | 88,17 | 0,83 |
| **On August 6** | The natural | 0,12 | 28,92 | 157,74 | 99,60 | 0,45 |
| | The intensive | 3,09 | 6,28 | 172,19 | 67,02 | 0,75 |
| **On August 22** | The natural | 6,54 | 9,81 | 167,31 | 59,99 | 0,68 |
| | The intensive | 5,53 | 10,33 | 150,13 | 65,14 | 0,62 |

The $R^2$ dynamics was found as synchronous with dynamics of value of an index of NDVI. The smallest $R^2$ value is observed in April when the vegetative cover practically is not present, and NDVI index during this period reflects heterogeneity of a soil cover. Except for a local maximum of value $R^2$ on May 2 in the field with natural technology (0,63), growth of value of an index of NDVI is interfaced to increase in a role of a trend in spatial variability of vegetative weight.

Distinctions on $R^2$ indicator between fields with different types of technologies are not statistically significant (Wilcoxon test *of* $Z = 0{,}18$, $p = 0{,}86$). It shows about similar nature of reaction of vegetation on both fields in reply to action of trend factors.

Variogram characteristics give important information on the spatial organization of the phenomenon or process at local level. The ratio of nagget-effect and a partial threshold indicate a space role in the variable organization, and the radius of autocorrelation shows extent of spatial interaction.

Values of nagget-effect and partial threshold are used for calculation of an indicator of spatial autocorrelation independence of a variable – *SDL*. It is obvious, logical to speak about spatial dependence therefore we will consider a complementary indicator – 100-*SDL*. Autocorrelation a component of spatial dependence it is also synchronous with phytomass. The indicator 100-SDL the smallest in the beginning of the vegetative period, grows with increase in an index of NDVI, and after achievement of a plateau the decreases is appeared. Feature consists that an indicator 100-SDL is significant larger for a field with natural technology of agriculture (Wilcoxon test *of* $Z = 2{,}19$, $p = 0{,}03$).

The radius of autocorrelation of an index of NDVI is not subject to natural change during the vegetative period and does not differ statistically between two fields (Wilcoxon test *of* $Z = 1{,}13$, $p = 0{,}26$). For a field with natural technology of cultivation this indicator is equal on the average 162,75 m, and for a field with intensive technology – 167,42 m. This fact can testify to the nature of emergence of phytomass autocorrelation. Most possibly that action local exogenous (in this case – edafic) factors leads to spatial structuring a vegetative cover. It is possible to tell that spatial heterogeneity of soil properties is a keys stone of formation of spatial patterns of vegetation that by definition is a basis for introduction of system of exact agriculture.

Important feature is the increase in a role of a trend and local autocorrelation at increase phytomass which is displayed by means of NDVI – more plentiful vegetative community becomes more spatial structured. Given result is an obvious spatial consequence of the law of a limiting factor of Libikh. With phytomass increase in the course of vegetation factors of the various nature and various large-scale level all more make the limiting impact.

As is shown in the fig. 5, optimum conditions for formation of production develop within a cluster 1. The worst conditions for primary production are noted for a cluster 2; clusters 3 and 4 are intermediate on NDVI values.

Features of profile distribution of mechanical resistance, characteristic for each cluster, are presented in fig. 6. The analysis of the data provided on drawing, shows that the main difference between clusters is intensity from which mechanical resistance with depth increases. For a cluster 1 which is characterized by the highest level of an index of NDVI, the gradual increase in mechanical resistance with depth is observed dew to in the root horizon with very small probability excess of threshold levels of mechanical resistance (3 MPa) may be reached. It should be noted that mechanical resistance of the soil on depths of 0-20 cm within a cluster 1 as a whole exceeds similar values in other clusters. But, observable values of mechanical resistance of the soil do not exceed critical value thanks to what such feature does not reduce possibility of growth and development of root system of plants, so and efficiency of a vegetative cover.

For a cluster 2 within which the worst conditions for development of plants by criterion of mechanical resistance are formed, the combination of high level of mechanical resistance in the top horizons (0–10 cm) and high level of mechanical resistance on depth 40–50 cm is characteristic. For clusters 3 and 4 low mechanical resistance of the soil in the superficial horizons and high mechanical resistance – in deep is characteristic. Distinctions between these clusters consist in on what depth the mechanical resistance sharply increases. In a cluster 3 sharp growth of mechanical resistance is noted from depth of 40-45 cm, and in a cluster 4 – from depth 30–35 cm.

Obviously, given on dynamics of mechanical resistance in space and in time can give the most volume and full information on nature of influence of this important indicator on efficiency agricultural field. Information on spatial variability of mechanical resistance of the soil at the end of vegetation before harvesting testifies that not only absolute value of mechanical resistance, but also nature of profile distribution (a profile form of mechanical resistance) are information and important indicators which influence operating on spatial variability of an index of NDVI and allow to describe its spatial features in time. The last circumstance allows to make the assumption of invariant character of a form of profile distribution of mechanical resistance in time.

In this case we understand similar nature of profile distribution of mechanical resistance as invariancy within each cluster. Absolute values of mechanical resistance can change in time, especially as a result of dynamics of soil moisture and mechanical impact on the soil of agricultural units. But after essential fluctuations, within each cluster the soil aspires to some steady state which for this cluster is characteristic. Profile distribution of mechanical resistance, in turn, influences distribution of moisture and a condition of growth of roots of plants and life of soil fauna.

In fig. 7 spatial distribution of the clusters allocated on mechanical resistance of the soil is presented. The cluster 1 occupies 15,92 % of the area of fields, a cluster 2 – 46,87, a cluster 3 – 16,98, a cluster 4 – 20,24 %. Thus, the area of lands with optimum conditions on mechanical resistance makes 15,92 %, and with the most adverse about a half – 46,87 %. The cluster 1 in the territory is presented by fragmentary loci – maximum on the area from which makes 37,79 % from the area occupied by a cluster. The cluster 2 represents almost solid formation – 90,37 % from the area of a cluster are occupied by the greatest locus. Similar indicators for clusters 3 and 4 make 44,28 and 63,78 % respectively.

Continuous character of an arrangement of a cluster 2 within which were created adverse conditions for growth of cultures on mechanical resistance, assumes possibility of local carrying out deep plowing for optimization of physical properties.

Thus, distribution of discrete units – clusters – within a field represents a basis for establishment of «management units». Management units – sites of a field which are characterized by homogeneous production requirements which differ from requirements of the next units of management within a field enough.

## CONCLUSIONS

1. Average values of mechanical resistance of the soil of experimental fields naturally raise with depth from 1,96 MPa in the top 15-centimetric layer to 4,02 on depth 45-50 cm. Distribution of indicators of mechanical resistance is the most distinct from normal law on depth of 15-30 cm from a surface.
2. Results of the cluster analysis allowed to allocate four clusters of sites. In space each cluster is presented by a quantity of accurately isolated patches with homogeneous mechanical resistance profile. The main difference between clusters is intensity with which mechanical resistance with depth increases.

3. The horizons which regularly are exposed to plowing (0-25 cm), at the end of a vegetative season are characterized by the mechanical resistance which variability in space is caused by geomorphological determinants. Regular plowing leds to evenness of mechanical properties of the soil at pedon level. In the under plowing horizon the pedon structure of the soil has enough time for restoration after the next deep plowing therefore on depth of 35-50 cm spatial structures in the size of 45-100 m in diameter are observed.
4. The allocated clusters determine productivity of an agroecosystem owing to features of profile change of mechanical resistance of the soil. Optimum conditions for efficiency are formed within a cluster 1. The worst conditions for primary production are noted for a cluster 2; clusters 3 and 4 are intermediate on NDVI value.
5. The cluster 1 in the territory is presented by fragmentary loci – maximum on the area from which makes 37,79 % from the territory which occupies a cluster. The cluster 2 represents almost solid patches – 90,37 % from the area of a cluster are occupied by the biggest locus. Similar indicators for clusters 3 and 4 make 44,28 and 63,78 % respectively. Continuous character of an arrangement of a cluster 2 within which adverse conditions for cultivation of cultures on mechanical resistance were created, assumes possibility of local carrying out deep plowing for optimization of physical properties of the soil.

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