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SOIL SPATIAL HETEROGENEITY AND SYSTEMS OF AGRICULTURE

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Aim. To consider soil continuality and discreteness as features of heterogeneity manifestation in a soil cover, important for construction of agriculture systems. **Methods**. Geostatistical research of soil spatial heterogeneity, revealing the contours of a field with various parameters of fertility. **Results**. The use of principles of precise agriculture and inspection of indicative properties of field soils using a regular grid allowed to divide a field into contours with three levels of fertility: the first one is characterized by optimal or close to optimum properties which allows refusing from (or reducing substantially) tillage, introduction of fertilizers or chemical ameliorates; the second one has average parameters of fertility corresponding to zonal soils and demands the application of zonal technologies; the third one (with the worst parameters of fertility) presupposes regular use of the improved technologies. **Conclusions**. The introduction of precise agriculture will allow replacing a traditional zonal system with thenew which is soil-protecting and resource-saving one.

Key words: soil continuality and discreteness, zonal and precise agriculture.

INTRODUCTION

There have been studies on different manifestations of heterogeneity, namely, continual heterogeneity, when spatial soil properties change gradually (simultaneously with soil formation factors), and discrete, intermittent heterogeneity, when soil properties change in the framework of small areas. Here the main factors of soil formation do not change. The interest to heterogeneity is quite reasonable as it is the actual basis for the agriculture systems – zonal, restricted to some zones, and precise agriculture, the specificities of which are formed regardless of the heterogeneity of the crop rotation field. Here the main attention is focused on precise agriculture as it corresponds to the spirit of the age the most – it allows protecting soil from degradation and saving resources (due to the abolition of activities in the part of the field where they are not required).

In order to understand the essence of the notions of continuality and discreteness of a soil cover, it is reasonable to recall some recent live discussions of this topic. In the 70–80s of the last century many outstanding scientists, geographers and soil scientists took part in discussing this issue. Armand D. L. adhered to the continuality principle, Stepanov I. N. – to the discreteness principle, Fridland V. M., Voronin A. D., Dmitriev E. A. believed that a soil cover is both a discrete and continual body at the same time (quoted from [1]). In recent years the interest to this issue has risen considerably, because there is more qualitative information, obtained by remote sensing methods, which are the most correct ones in estimating these properties of a soil cover. Any regular network of dots, however thick it is, does not measure up to a real map, obtained by a remote sensing method. For this reason the application of some remote spectrometric means allows interpreting a soil cover as mainly a continual object, where the properties (heterogeneity) gradually change in space [2, 3]. At the same time the radar probing in the vertical direction always reveals heterogeneity in the profile composition, which may be explained by the changes in soil texture, density and humidity [4, 5].

Therefore, it is reasonable to state that the soil cover in a 2-D format is mainly a continual formation, the continuality of which is disrupted only due to a complex composition of valleys and bottom land, high-relief terrain in submountain regions and mountains, due to alteration of different types of vegetation and other reasons. At the same time in a 3-D format the soil cover is an evident continual-discrete formation due to genetic horizons, different in their composition and structure (especially in the differentiated soils). Most probably, soil is discrete in a 4-D format as well, when the abovementioned formats are added time as a factor of the soil cover transformation. It is well known that in the course of long-term use the soil loses humus, there are new features in its morphology, properties and regimes. All the abovementioned facts allowed defining a new type of soil – agrozem, this term appeared in soil classifications of Russia, Belarus, Ukraine and other countries. These changes in the soil cover enhance its heterogeneity in space and promote the occurrence of new boundaries [6]. Thus, time becomes a factor of discreteness of the soil cover.

Unfortunately, it should be admitted that the soil cover has been mainly studied as a continual and very little – as a discrete body, especially if viewed at a peculiar medium hierarchy level (in terms of spatial heterogeneity of many soil properties in the framework of a polypedon or, in the context of this article – a crop rotation field). Certainly, it inhibits successful development of the notions of a horizontal profile of soils and, as a consequence, practical applications of heterogeneity to precise agriculture.

The aim of the article is to consider continuality and discreteness as specificities of the manifestation of heterogeneity in the soil cover, relevant for the establishment of an agriculture system, new boundaries in the soil cover, formed due to the investigation of indicative properties of soils in the regular network of dots as well as the value of new boundaries for precise agriculture.

MATERIALS AND METHODS

We made an attempt to use the traditional notions about spatial specificities of soil properties with the purpose of improving modern agriculture practice, especially precise agriculture, including the ways of finding the boundaries of contours with different fertility indices. The materials of long-term studies of spatial heterogeneity of soils in Polyssia, Forest-Steppe and Steppe, summarized in monographs, were used in the work [6, 7].

Six fields were used as objects, three of which are located in Polyssia (Romaniv, Kolky and Vediltsy), two – in the Forest-Steppe (Korotych and Kommunar) and one – in the Steppe (Donetsk).

Romaniv (Volyn' Region). Gray podzolic, sod-podzol and gleyed black soils prevail in the soil cover. The terrain is flattened. The soil texture is light clay loam. The size of the field is 63 ha, the number of elementary patches is 35. Cereal and forage crops are cultivated. The agrotechnical methods of crop cultivation are not differentiated, regardless of evident mottling of the field.

Kolky (Volyn' Region). The soil cover is a complex of sod-podzol gleyed, sod-gley and meadow-bog soils. The terrain is flattened. The soil texture is argil sand. The size of the field is 11 ha. The number of patches is 27. Forage crops are cultivated (on the non-boggy part). The field has been dewatered by an open network of channels, which function only partially, unfortunately. The studies have been conducted only on the non-boggy part. The agrotechnical methods are not differentiated in the field.

Vediltsy (Chernihiv Region). Sod-mesopodzol loamy soils. The terrain is flattened. The size of the field is 105 ha, some part of the field is grassy, the number of patches on the non-grassy part is 117. Cereal and forage crops are cultivated.

Korotych (Kharkiv Region). Dark grey heavy loamy podzolic soil prevails. The terrain is slightly sloping. The size of the field is 31 ha. The number of patches is 35. Cereal and forage crops are cultivated by the method, traditional for the forest-steppe.

Kommunar (Kharkiv Region). Typical, low humus, leached, heavy loamy chernozem. The terrain is flattened. The size of the field is 30 ha. The number of patches is 26. Cereal and forage crops are cultivated.

Donetsk (Donetsk Region). Typical heavy loamy chernozem. The terrain is flattened. The size of the field is 105 ha, the network of patches (51) is established on the part of the field of 50 ha. Cereal and forage crops are cultivated.

RESULTS AND DISCUSSION

Modern agriculture systems and their drawbacks. The solution to a large complex of issues, related to the enhancement of soil fertility, its protection, rational use (with the consideration of the terrain, climate, economic and social demand, ecologic requirements) depends on the agriculture system. It includes the issues of rational balance of the fields, the structure of planting and crop rotations, introduction of fertilizers, application of chemical and other kinds of amelioration, agrotechnical methods. The role of zonality, microzonality and landscapes in the location of crops is defined in the agriculture systems rather objectively and comprehensively – it is a very wide scope of problems, solving which is focused both on meeting the needs of population in food products, and the need of production in raw materials, but also on the stable character of agriculture at present and in the long run. However, there are many claims regarding modern agriculture systems as the latter have been the reason of multiple manifestations of degradation and worsening of soil quality. Their main drawback, considered in this article, is a too generalized content, corresponding to the conditions of the natural zone (which is why they were called zonal agriculture systems), and ignoring spatial specificities of a specific field of a crop rotation.

For instance, the zonal agriculture system in Polyssia may be considered the most intensive. Sod-podzolic soils, prevailing in this zone, have an acid reaction of the soil solution, sandy and loamy soil texture, it quickly restores its increased initial density after the tillage, and easily forms a superficial crust due to the intensive increase in the temperature in spring. Due to the increased amount of rainfall, sloping in the terrain and often shallow compacted illuvial horizons these soils have the signs of being gleyed. In addition, Polyssia soils are mainly deficient in nutrients. Due to the above mentioned specificities the agriculture system in this zone requires multiple tillage, introduction of fertilizers and lime. Still, it is just a general scheme. As shown below using the example of investigated fields, their morphological, physical and physical-chemical properties, this universal approach based on the averaged zonal characteristics requires considerable corrections regarding practically all the components of the agriculture system.

The same is true regarding the soils of the Forest-Steppe. Typical chernozem, podzolic and dark grey soils of medium and heavy loamy soil texture with good structure and introduction of humus, and moderately dense structure dominate in the soil cover; they are mainly provided with nutrients and have the medium reaction, close to optimum. At the same time they are not water-resistant enough, often too compacted in the furrow bottom and in the underplanting layer after the spring cycle of tillage, and they are inclined to the formation of lumps, crust and cracks. The drawbacks of these soils are not manifested on the whole field, they are remarkable for its boundaries or sloping. The soils of Forest-Steppe are characterized by the processes of dehumification and loss of calcium, due to which the soils are inclined to the destruction of aggregates and acidification of soil; these processes are not global, they are manifested only in specific parts of the field.

As shown in multiple 2-D and 3-D diagrams, the soil cover of the field in the Steppe is also heterogeneous, the morphological, physical and physical-chemical properties of the field soil vary in space which actualizes the problem of differentiating the agriculture systems in this zone as well.

The abovementioned is of exclusive importance for the differentiation of agrotechnologies in accordance to actual parameters of the field soil. If the field properties – the ones, determining the content of agrotechnologies (structure density, content of nutrients, etc.) – did not have any expressed mottling, the latter could be neglected and the field could be cultivated with even introduction of fertilizers on the whole space. Unfortunately, it does not correspond to reality. There are more and more data on the heterogeneity of fields regardless of genesis and the level of previous tillage of soils [7]. The heterogeneity is manifested even in the field where the elements of high farming standards were applied for almost 150 years [8] which allowed for the conclusion on the heterogeneity as a property, immanently inherent to soils.

At present some fields of crop rotations are not subject to detailed study using a regular network of dots. Even in case of agrochemical certification, when it could have been done without the increase in expenses, the preference is given to the reconnaissance survey, performing which does not provide any adequate notion on the spatial heterogeneity of the field [9]. For this reason in any natural zone the agriculture system is based on the averaged indices of soils and climate without the consideration of specific field specificities. Certainly, the changes in landscape are considered for significant sizes of natural zones. In this case the agriculture system reflects the peculiarities of accumulative, transit and automorphous territories. The same is true for climate – the share of moisture-retaining technologies increases in more arid conditions. However, the application of the zonal agriculture system presupposes gradual change in the soil cover in the boundaries of the natural zone, reflecting only the continual constituent of heterogeneity and ignoring the heterogeneity in the framework of the crop rotation field.

The discreteness of the field in precise agriculture using fertility norms. The notions of the soil cover as a discrete formation are being formed in precise agriculture, as the purpose of the latter is to detect the patches with different fertility in the field and then to make the technology of cultivating crops more discrete. The discreteness in these notions is a compulsory measure, as it is a more convenient and easier way of implementing the principles of precise agriculture. At the same time these notions are nothing but an artificial transformation of the continual soil cover into the discrete one.

How can one interpret regular interchange of structures with specific properties, revealed in actual soil cover? Is it discreteness, intermittency, or continuality, a mistake? In the work [6] this interchange is viewed as a manifestation of continuality and graduality in the change of properties. Here the discreteness is introduced via the application of interpolatory (somewhat formal) kriging-methodology, when the graduality is artificially interrupted with classic subdivisions of properties. 2-D diagrams, numerously used by the author (in this case block kriging is not applied in their creation), demonstrate the graduality of the interchange of properties in the space of all the investigated fields [6].

Below are the norms, serving as a basis for the transformation of the continual soil cover into the discrete one (Table 1, 2). These norms have been obtained by the authors on the basis of literature data and adaptation of recommendations to the specificities of precise agriculture, indicated therein [6].

Precise introduction of organic fertilizers comes first. The parts of the field, where stable increased humus content was registered in the course of several evaluation courses, were used to prove the possibility of refusing from the introduction of manure. The average norm of manure, based on the possibilities of the farm, should be introduced in the parts of the field, where the deviation from the previous content reaches –5...–10 %. Finally, the increased norm of manure should be applied in the parts of the field, where the content is 10 % less than the increased level, or even more (Table 1).

Traditionally the data on crop yield is nearly the only source of information for planning precise agriculture and, in particular, for introducing organic and mineral fertilizers. There is an attempt to use these data in this work, although the author has his own and more accurate information on the spatial heterogeneity of practically all the main macroelements of nutrition and other factors of fertility and yield in the investigated fields. As stipulated above, the spatial heterogeneity of the data about the yield of cereal crops and sunflower is

Table 1. The rationing of the introduction of fertilizers and lime in precise agriculture

Mineral fertilizers			Organic fertilizers		Lime application	
Index	Content, mg/kg of soil	Norm of introduction	Deviation from the average content, %	Norm of introduction	pH	Scenario
Total mineral nitrogen	> 30 30–15 < 15	0 By removal with expected yield The same + additionnal amount due to variant 0	Stable increased content for 2–3 courses of agrochemical certification	0	7.0−5.5	Without melioration
Mobile phosphorus (by Chirikov)	>150 150–50 < 50	0 By removal with expected yield The same + additionnal amount due to variant 0	−5 … −10	Average estimated introduction, based on the possibilities of a farm	5.5− 5.0	Sustaining melioration
Mobile potassium (by Chirikov)	> 120 120–40 < 40	0 By removal with expected yield The same + additionnal amount due to variant 0	−10 and above	The same + additional amount due to economy in variant 0	< 5.0	Systematic introduction of lime in higher doses

moderate and reflects some averaged value of spatial heterogeneity of all the investigated indices, including the cases when the spatial heterogeneity of the yields was analyzed in the aftereffect (Korotych, 2 years of aftereffect, Kommunar, 1 year of aftereffect). Rather coordinated data about the spatial heterogeneity of the humus content and yields were received only for the objects of Romaniv and Donetsk. Almost complete coincidence of heterogeneity was revealed in these cases. Some differences were present in other objects. Here the data about the spatial heterogeneity of humus content were used for the delimitation of the field. In general the coincidence of fields was proven satisfactory in the observations of the productivity in aftereffect as well.

If the pH value of the soil is in the subacid/neutral interval, which is favorable for all the crops, cultivated in the Forest-Steppe, and almost all the crops of Polyssia, lime application is not required. From 30 to 80 % of such patches were found in the investigated fields which is a relevant fact as usually lime application of acid soils in these natural zones is performed along the whole area of the fields without any exceptions. Considerable economy of lime materials is evident. The norm and regularity of amelioration increase with the rise in acidity. According to the data about the spatial homogeneity of the soil solution reaction, full-scale lime application is required for only one field on the Kolky object.

An additional argument in favor of the research activity and implementation of precise agriculture in the sphere of tillage practice is the data on the ratio of zones with favorable, less favorable and unfavorable agrophysical conditions on the investigated fields. Thus, the recommendation on differentiating zero (no tillage), minimal and traditional tillage on the fields becomes clear. The higher the share of patches with favorable parameters of balanced bulk density on the field in the pre-sowing period or prior to the main tillage is, the more relevant the precise tillage becomes (Table 2).

According to the data of Table 2, potential possibilities of reducing the intensity of the pre-sowing tillage of soil and even completely refusing from tillage turned out to be surprisingly high even on the soils with unfavorable agrophysical conditions. It should be noted that the evidence to this fact can be found in the works of some other authors [10].

The boundaries in the soil cover for precise agriculture. Precise agriculture applies new boundaries to divide the soil space into separate contours. The latter act as independent working areas, on condition that their sizes provide for economically profitable operations.

Precise agriculture and new technical possibilities of mapping, based on geoinformational technologies and remote means became the tool of obtaining principally new mapping information. These are electronic digital maps. As the contours of soil properties on these maps almost never coincide with the contours (of kinds and even higher taxonomic units) on the traditional soil maps, the connection between these two maps has been lost. Gradually precise agriculture has not had any need

Table 2. The standards of estimating physical properties to substantiate the intensity of tillage practice*

Index	Qualitative estimate of the tilled soil layer	Recommendation on intensity of pre-sowing tillage
Number of blocks in the sowing layer, %:		
< 5	Favorable	No tillage needed
5–15	Satisfactory	Moderate tillage
> 15	Unsatisfactory	Intense
Bulk density in the sowing layer, g/ccm:		
< 1.2	Favorable	No tillage needed
1.2–1.3	Satisfactory	Moderate tillage
>1.3	Unsatisfactory	Intense
Penetration resistance in the furrow bottom, kgf/sq.cm:		
< 20	Favorable	No tillage needed
20–40	Satisfactory	The same
> 40	Unsatisfactory	Intense

*The standards are applicable to soils of medium and heavy loamy soil texture.

in using the soil map to plan agrotechnical operations. It should be noted that previously the same happened to the agrochemical map of available nutrients content in the soil. The boundaries of soil contours and the boundaries of providing soils with nutrients do not coincide on these maps. Usually the agrochemical map contains much fewer contours which is very convenient for production purposes. Instead of the soil map, the agrochemical one was used to plan the introduction of fertilizers on the farms.

Precise agriculture has got a new foundation – partial analysis [11] of the soil cover, i.e. spatial (geostatistical) analysis of the heterogeneity of specific properties of soils, relevant for planning of agrotechnical operations. These properties were called indicative in our laboratory; their systematization was performed.

In these conditions the soil scientists sounded the alarm, as the very basic concepts of the theory on the soil cover structure as an integral soil unit were challenged. Gorjachkin [11] cites a number of interesting references to the works, published in Russia and other countries.

The idea of Kozlovsky [12] about the soil individual as an attempt to unite the traditional [13] and geostatistical approaches, which seemed quite rational to some researchers [14] and to the author of this article at first [7], is likely to require substantial stipulations and modification. The soil individual as an elementary primary unit may actually become a link, connecting two approaches, but its application in precise agriculture as a working area cannot be eligible due to extremely small horizontal sizes – from 0.6 to 12 m [15]. Actually, it cannot as of date only. In future, when there is new equipment for agrotechnological operations with high resolution capacity, this possibility may be real. Still, in any case, the idea of uniting elementary units into larger ones, the economic activity on which will be economically profitable, should be developed in precise agriculture.

Thus, the soil map, obtained on the basis of studies in the non-regular network of "typical" sections, mainly, the profile morphology, the boundaries of which are defined using the local topography, cannot coincide with the map, developed on the basis of investigations in the regular network of sections and analytical data, processed using formal kriging-methodology of data interpolation. To verify this fact, one may compare the soil map of one of the investigated objects (for instance, Romaniv) and 2-D diagrams (Fig. 1, 2). Previously there were comparisons of the elementary soil area ac-

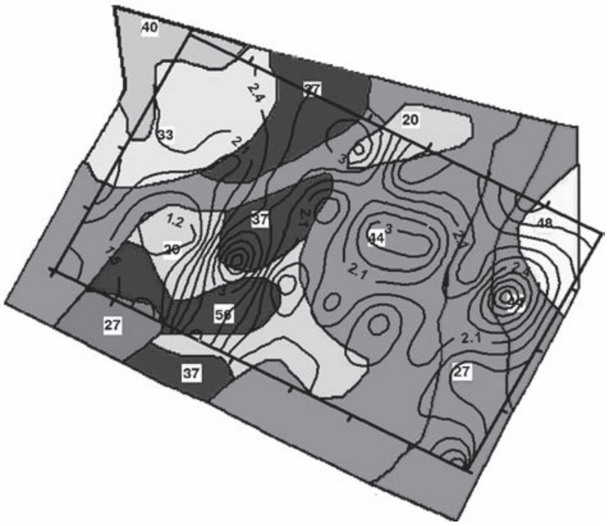

Fig. 1. The alignment (co-kriging) of the soil map of Romaniv object with the 2-D diagram of humus content. Soil types are shown in grey shades, humus content (%) – by isopleths

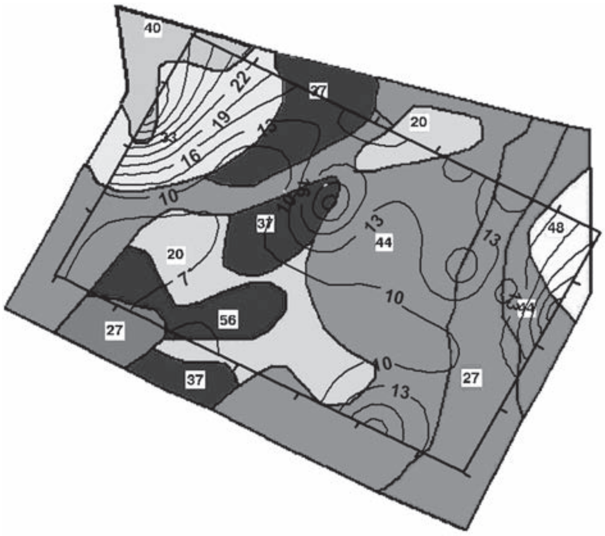

Fig. 2. The alignment (co-kriging) of the soil map of Romaniv object with the 2-D diagram of mobile phosphorus content. Soil types are shown in grey shades, phosphorus content (mg/100 g of soil) – by isopleths

cording to Fridland and the soil individual, estimated according to Kozlovsky. The result was evident non-coincidence of the contours and their sizes.

At the same time a relevant unifying moment of the maps, created on the basis of two approaches, differing in their principles, is the terrain. This factor serves as a specific moderator in the final determination of contours on the traditional map. At the same time it is the reason of forming heterogeneity. Therefore, there should be some similarity between the traditional and geostatistical maps. However, it is considerably dis-

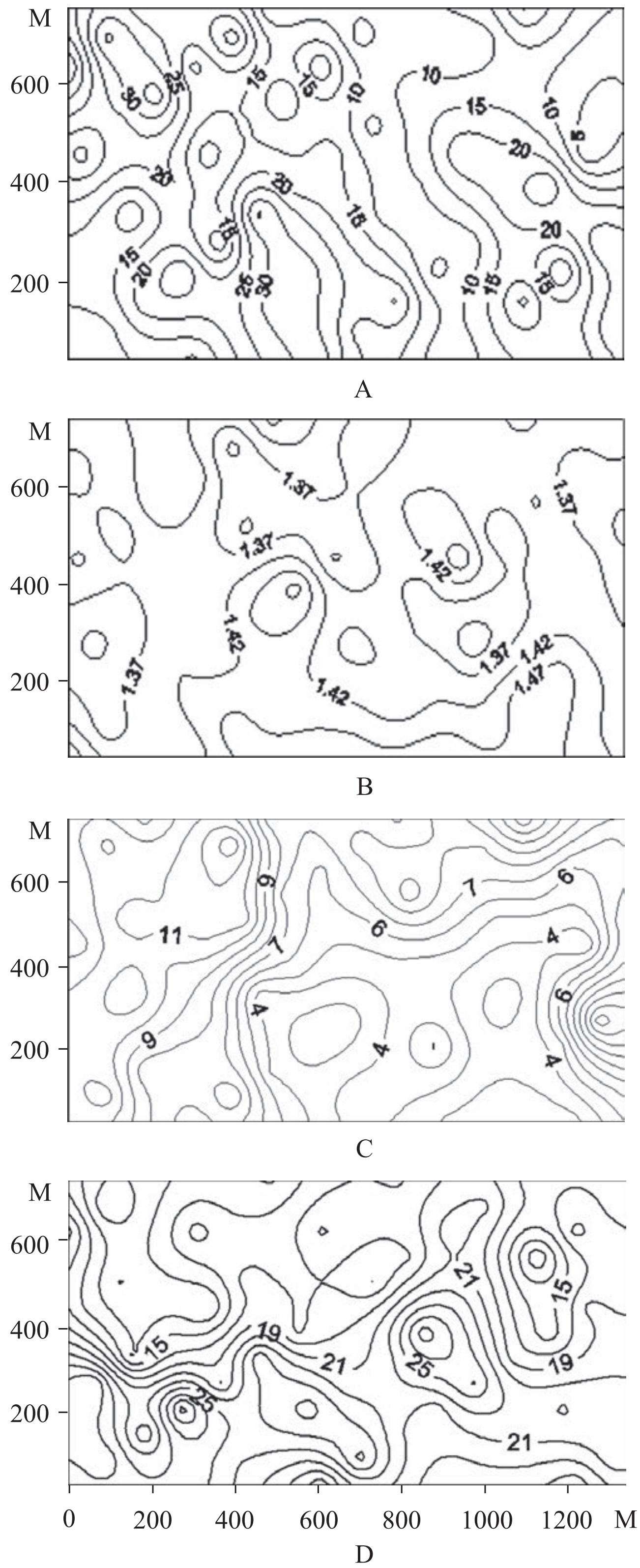

Fig. 3. 2-D diagrams of spatial heterogeneity of the content of blocks (*A*, %), equilibrium bulk density (*B*, g/ccm), mobile nitrogen forms (*C*, mg/kg of soil) in the sowing layer and the grain yield (*D*, feed units), sod-podzol soil (Vediltsy)

guised by the anthropogenic activity as the introduction of fertilizers, ameliorants, soil tillage and any other human activity enhances heterogeneity. This is precisely why in the author's opinion [6] and according to much other data [8, 16] the spatial heterogeneity of the content of mobile nutrients in soil reaches extremely high values.

Noteworthy is another relevant reason of non-coincidence of boundaries on the maps, namely, differences of defined analytical characteristics. A soil map is usually created without the consideration of physical, physical-mechanical and agrochemical characteristics, whereas these very properties are the basis of the indicative estimates, used to plan the introduction of mineral fertilizers, ways and depth of tillage, other agrotechnological operations in precise agriculture.

But the main reason of the non-coincidence of the soil map, obtained on the basis of "typical" sections, and the map, developed on the basis of a regular network of the test run, is the fact that in the former the soil cover is a discrete body, the properties of which change jump-like, while in the latter it is a continual body, the properties of which change gradually.

The application of modern software made the creation of the map of any soil property a simple and very productive procedure. Moreover, it is possible to perform various transformations with maps in the computer program. It is easy to change the legend in order to increase or decrease the number of contours, to calculate their areas or even create various spatial models, the samples of which have previously been demonstrated [6]. These and many other transformations are possible without printing and manual operations, without extracting the map from the computer. In its essence it is a virtual map, wide-spread both in precise agriculture and beyond it. Moreover, it should be admitted that the study of the experience of precise agriculture in the USA and Germany, and, according to the literature data, in many other countries, including the experience of the leading researchers of this trend [8, 17] leads to the conclusion that a soil map is not required to plan precise agriculture. More precisely, if the structure of the soil cover was registered in the land tenure projecting accurately, and the studies of the indicative properties of soil were conducted using the regular network of the selection points, then the search for the most reasonable working places to organize the differentiated introduction of fertilizers and performing other precise agrotechnological operations may be conducted, using the maps of indicative properties of soils instead of the soil map. A soil map would be required only if spatial planners make a mistake while cutting the fields, like when it happened on the Romaniv object, and unite non-compatible soils in the framework of one crop rotation field. The subsequent experience of working on this field demonstrated that its part has to be taken out of active use and left for grass. Therefore, this mistake was corrected without the soil map.

Certainly, one may not flatly refuse from the soil map. It is only a question of the sufficiency and possibility of planning precise agriculture, taking into account the virtual maps of specific indicative properties of soils. As for the fundamental scientific concept of the soil cover structure, actual soil maps, synthesizing "private" information and forming the notion on the soil cover as an integral natural formation, the refusal from it or any revision is out of the question. On the contrary, the new information about the soil cover, which previously was not accounted for in the development of the concept of the soil cover structure, will allow improving the theory and especially its practical applications.

The reason of non-coincidence of soil maps, the maps of soil cover structures and the maps, used in precise agriculture, is explained by the fact that the contours on the soil maps are isolated using the traditional soil-geographic principles, ignoring the indices of soil fertility to some degree. The agricultural purposes require establishing both permanent (regular) boundaries between specific parts of the field and the temporary (random) ones, formed synchronically with weather changes, the technology applied, development

Table 3. The ratio of areas with the application of different ways of pre-sowing tillage on the investigated objects depending on the level of equilibrium density of soil structure, %

Object	Tillage		
	No tillage	Minimal	Standard for the zone
Vediltsy	10	50	40
Romaniv	60	30	10
Kolky	25	40	35
Korotych	50	40	10
Kommunar	70	25	5
Donetsk	75	22	3

Table 4. The ratio of areas on the investigated fields with different levels of applying mineral and organic fertilizers and scenario of chemical amelioration, %

Object	Mineral fertilizers				Organic fertilizers			Scenario of chemical amelioration		
	Kind	No fertilizers	For expected yield	The same + addition	No fertilizers	Average amount –	The same + addition	No amelioration	Sustaining	Standard
Romaniv	N	100	0	0	14	65	21	30	26	44
	P	21	79	0	–	–	–	–	–	–
	K	37	63	0	–	–	–	–	–	–
Kolky	N	100	0	0	45	17	38	80	13	7
	P	0	22	78	–	–	–	–	–	–
	K	0	42	58	–	–	–	–	–	–
Vediltsy	N	0	0	100	20	53	27	0	0	100
	P	70	26	4	–	–	–	–	–	–
	K	24	73	3	–	–	–	–	–	–
Korotych	N	0	17	83	9	47	44	45	35	20
	P	28	72	0	–	–	–	–	–	–
	K	90	10	0	–	–	–	–	–	–
Kommunar	N	15	85	0	30	62	8	39	61	0
	P	100	0	0	–	–	–	–	–	–
	K	100	0	0	–	–	–	–	–	–
Donetsk	N	0	42	58	1	87	12	–	–	–
	P	10	90	0	–	–	–	–	–	–
	K	15	85	0	–	–	–	–	–	–

and state of the crop. That is why the concept of the soil cover structure is not sufficient for the purposes of precise agriculture.

Therefore, it seems reasonable and quite justified to introduce new boundaries in the soil cover, based on lateral study of soil properties – morphological, physical, physical-mechanical and others. These boundaries were used to substantiate the configuration of production working places for differentiated application of agrotechnological operations.

The ratio of areas of field soils with different level of fertility. In conclusion it is logical to demonstrate the ratio of areas with justified different, zero, in particular, agrotechnology in the investigated fields. The 2-D diagrams obtained (see samples in Fig. 3) and the above-mentioned standards may be used for this purpose. It is noteworthy (Tables 3 and 4) that even in the fields of the most problematic zone of Polyssia their considerable part does not require intensive tillage, lime application or even introduction of fertilizers. The system of agriculture on all the other fields should be equally precise. It is clear that the larger the area of the field, allowing the minimization of agrotechnologies, is, the higher economic and ecological advantage of precise agriculture is. In the author's opinion, the data obtained explain increasing attention to precise agriculture in the world [8, 17] and its evident promising future in Ukraine.

CONCLUSIONS

Continuality and discreteness were considered as the forms of manifestation of heterogeneity of the soil cover, used in the elaboration of zonal and precise systems of agriculture, respectively. A notion of indicative properties and standards of soils, due to the application of which the continual soil cover becomes discrete, was introduced.

Precise agriculture is based on new soil boundaries, which form the contours with different levels of fertility for the differentiation of the components of the agriculture system in the crop rotation field.

The application of principles of precise agriculture and the investigation of indicative properties of field soils according to the regular network allowed dividing the field into the contours with three levels of fertility, one of which is characterized with optimal or close to optimum properties, which allows refusing from (or reducing considerably) the application of tillage, introduction of fertilizers of chemical ameliorants.

The introduction of precise agriculture will allow replacing the traditional zonal system of agriculture with the new – soil-protecting and resource-saving one.

Просторова неоднорідність ґрунтів і системи землеробства

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Мета. Розглянути континуальність і дискретність як особливості прояву неоднорідності в ґрунтовому покриві, важливі для побудови систем землеробства. **Методи**. Геостатистичне дослідження просторової неоднорідності ґрунтів, виявлення контурів поля з різними параметрами родючості. **Результати.** Використання принципів точного землеробства і обстеження індикаторних властивостей ґрунтів полів за регулярної сітки дозволило поділити поле на контури з трьома рівнями родючості: перший характеризується оптимальними або близькими до них властивостями, що дозволяє відмовитися від здійснення обробітку (або істотно його скоротити), внесення добрив або хіммеліорантів; другий − із середніми параметрами родючості, які відповідають зональним ґрунтам, потребує застосування зональних технологій; третій (з найгіршими параметрами родючості) – вимагає систематичного використання поліпшених технологій. **Висновки.** Впровадження точного землеробства дозволить замінити традиційну зональну систему землеробства точною – ґрунтозахисною і ресурсозберігаючою.

Ключові слова: континуальність і дискретність ґрунтів, зональні і точні системи землеробства.

Пространственная неоднородность почв и системы земледелия

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Цель. Рассмотреть континуальность и дискретность как особенности проявления неоднородности в почвенном покрове, важные для построения систем земледелия. **Методы.** Геостатистическое исследование пространственной неоднородности почв, выявление контуров поля с различными параметрами плодородия. **Результаты.** Использование принципов точного земледелия и обследование индикаторных свойств почв полей по регулярной сетке позволили разделить поле на контуры с тремя уровнями плодородия: первый характеризуется оптимальными или близкими к ним свойствами, что позволяет отказаться (или существенно сократить) от осуществления обработки, внесения удобрения или химмелиорантов; второй − со средними параметрами плодородия, соответствующими зональным почвам, требует применения зональных технологий; третий (с наихудшими параметрами плодородия) – предполагает систематическое использование улучшенных технологий. **Выводы.** Внедрение точного земледелия позволит заменить традиционную зональную систему земледелия точной – почвозащитной и ресурсосберегающей.

Ключевые слова: континуальность и дискретность почв, зональные и точные системы земледелия.

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