The Social Sciences 11 (13): 3361-3365, 2016
ISSN: 1818-5800

Rationale for Indicators of Arable Farming Duration (Based on Research Findings in the County of the Antique Polis of Kerkinitis)

Fedor N. Lisetskii, Olga A. Marinina, Ruslan S. Gadzhiev and Evgenia Ya. Vorobyeva
Belgorod State National Research University, Pobedy Str. 85, 308015 Belgorod, Russian Federation

Abstract: Using the results of determination of macro-and micronutrients content, physical and chemical properties of soil and biogeochemical indicators we carried out the comparison of arable carbonate Chernozems of Crimea steppe zone which differed by duration of arable farming. The objects of study were the following: cultivated soil which is located in the rural district of the Antique Polis of Kerkinitis and soil-analogue in the area of new (since the 21st century) period of development. From 90 indicators being analyzed the most informative indicators of duration of agro genesis were validated through statistical methods. They reflect the processes of weathering, leaching, secondary calcareous invasion, accumulation of a number of elements and dehumification in fine part of soil. It is shown that the processes of agrogenic transformation in old arable soils and modern-day plowed land are going on at different levels of structural organization of soil system.

Key words: Ancient farming, Kerkinitis, rural district, chora, duration of arable farming, old arable soil, indicators of agrogenesis

INTRODUCTION

In recent years in the studies of ancient agricultural areas there has been a significant progress by application of the interdisciplinary approach (Homburg and Sandor, 2011; Lisetskii, 2012; Lisetskii and Rodionova, 2012; Lisetskii *et al*., 2012; Smekalova *et al*., 2015a). This allows starting geo-archaeological study of rural district of ancient policies, historical and archaeological information about which is objectively hypothetical.

On the territory of Crimea significant research interest is coursed by spatial location and geometric parameters of the long functioning rural district of ancient Kerkinitis (beginning of the last third of 6-2 centuries BC). Solution of this problem is especially important for understanding economic situation in West Crimea under the new configuration of frontiers of Tauric Chersonese in the period from the beginning of the 3-4 quarter of the 4th c. BC till the third quarter of 2nd c. BC when Kerkinitis was a part of it (Kutaysov, 1990). It is possible that traces of demarcation of land to the west of Yevpatoria that are poorly readable in the aerial photographs and satellite images are connected with the organization of one of the massives in distant Chora that Chersonites created for 4th BC in the Western and North-Western Crimea.

The decree on the distribution of the polis's lands fund in Issa can give a certain idea of the practice of land distribution within the civilian community which belonged to Greek colonists. According to this decree outside the city walls polis's lands formed their own Chora including the land for main allotments (first settlers received 0.57 ha each), the rest of the land, as well as undivided share of land. Historians' ideas about the size of agricultural district of Kerkinitis are contradictory. At an early stage (from the second half of the 6th c. BC till mid-4th c. BC) Chora of Kerkinitis was localized in the immediate neighborhood of the city but we can say with reasonable certainty that in the 4th-2nd c. BC a more extensive rural district was divided into allotments by road system. Summarizing the views of Kutaysov (2004) notes that the Chora of Kerkinitis occupied the area from the Black Sea to Moinakskoye lake but not only in the western but also in the eastern direction within a radius of about 3 km from the walls of Kerkinitis (Kutaysov, 2013). According to the "Plan of settlement near Yevpatoria in 1880" by Burachkov (Burachkov, 1881, table III) the coastal strip with burial mounts and necropolis discovered up to the mentioned "tree traces" (1.1 km from the sea), probably, was not included in an agricultural zone. Two landscape tiers are represented here: lowland littoral tier with salt marshes and sandy sod soils and hydromorphic tier with meadow-chestnut saline soils which are not very suitable for efficient farming. However, it should be borne in mind that in ancient times the coastline had a different shape and the modern coastal zone is a new formation.

Corresponding Author: Fedor N. Lisetskii, Belgorod State National Research University, Pobedy Str. 85, 308015 Belgorod, Russian Federation

As Kutasov (2013) supposed polis's agro-zone extended inland of the peninsula for no >2.5-3.0 km and the cultivated area could amount to about 1,300-1,400 ha. However, in his subsequent works, this researcher revised his views: he believes that Kerkinitis district covered an area of about 80-90 km^2 which was located in the form of a strip of up to 7 km wide along the coastline between Lake Kyzyl-Yar in the South-East and the Donuzlav in the North-West for 65 km. Only arable lands for major crops (wheat and barley) covered 5050-5519 ha (Kutaysov, 2013).

MATERIALS AND METHODS

The area to the North-West of Yevpatoria is a part of the Crimean southern steppe agropedological province with plains, low angle wavy landscape with heights from 5 m above sea level (in the South) to 35 m a.s.l. (in the North). At the western edge of Yevpatoria Lake Moynakckoe is located; it was a bay in ancient times. Among the parent rocks loess soil and residual and talus carbonate rocks dominate. Chernozems are mainly carbonate on eluvium of dense and carbonate rocks as well as carbonated ones which are close to the micelle-carbonate Chernozems on loess sediments but differ from them mainly by rubble dope to the fine Earth. Ash soils and ash pans are also found here.

Within the large-scale field studies of soils to the north-west of Yevpatoria (over 120 sampling points in the area of 6600 ha), the results of which require separate consideration, two typical objects were determined, on which the complex of profound analytical studies was conducted in the laboratory (Fig. 1). Both soil objects are in the loop of carbonate arable black soil but the incision p 53 is located 2.8 km to the West of moinakskoye lake and taking into account the total available ideas of the ancient farming it characterizes the continually plowed land which was cultivated within the Chora of the ancient polis and was subjected to agrogenic transformation in modern times and incision p 36 (7 km from the sea, 11.7 km to the Northwest of Kerkinitis) refers to the area of a new period of development (duration of arable farming-150-165 years). Additionally raised and previously published data (Lisetskii *et al*., 2015) on the continually plowed land (p 19)-surface carbonate slightly calculous Chernozems 1.4 km to the Northwest of p 53 with the following morphological structure: 0-17 cm-plowing horizon; 17-27 cm-sub plowing horizon; 27-54 cm-transitional horizon.

Bulk chemical composition of the soils was measured by X-Ray Fluorescence (Spectroscan Max-GV). XRF has shown to be effective in the study of the artefacts of the Bronze and the Iron Age (Jusoh *et al*., 2012). Soil particle-size data obtained with the help of pipette method with the use of sodium pyrophosphate.

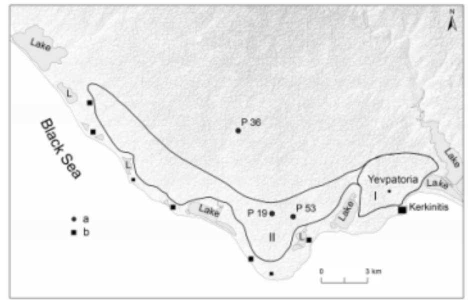

Fig. 1: Potential areas of agricultural land development near the antique polis of Kerkinitis Note. I approximate area of agricultural land area of 1300-1400 ha; II approximate area of arable land 5050-5519 ha (Kutaysov, 2004); a places of soil excavation (P No); b ancient Greek settlement

To determine the color of dry soil Munsell book of Color was used Munsell Soil Color Charts. Assessment of Soil Quality (SQ) taking into account the content of macronutrients required for plants (K, Mg, Ca); minor-nutrient elements (Mn, Fe, Ni, Cu, Zn) and mineral elements (Si, Al) in the soil was carried out according to the formula:

$$SQ = (B_1 \cdot B_2 \cdot ... B_{10})^{1/10} \quad (1)$$

where, $A_1...A_{10}$ is the contents of the above elements. According to Liu *et al*. (2009), the leaching coefficient is calculated in accordance with the formula:

$$Ee = SiO_2/(CiO+K_2O+MgO+Na_2O) \quad (2)$$

The total index of soil pollution with heavy metals is calculated as an average geometric value. The review of other proposed geochemical indicators of pedogenesis and their interpretation are presented in the study.

To prove the difference between the associated pairs of observations (judging by the set of indicators the continually plowed land and newly cultivated soil) a non-parametric Wilcoxon test (W) was used. Variance analysis of soil properties was carried out with the use of Microsoft Office Excel.

RESULTS AND DISCUSSION

During considerable period of arable farming some hardly (not) convertible evidence of properties changes may be reflected in the sol memory. In this connection the

Table 1: Agrochemical and agro-ecological indicators of arable horizon of carbonate Chernozems from areas: ancient arable farming (p 53) and a new period of cultivation (p 36)

Name of indicator	Unit of measurement	Number of soil crossover P 36	P 53
Color (dry), Munsell	-	10 YR 4/3dark brown	10 YR 5/4yellowish brown
Agrochemical indicators			
Organic substance (soil)	%	2.7±0.54	2.6±0.54
C org (<0.25 mm)	%	1.35	1.18
C org (<0.05 mm)	%	1.49	1.21
pH (H_2O)	-	8.36	8.30
CaCO3		%	5.98 9.44
N hydrolizable	mg/kg	112±11	112±11
Movable hydrocarbon P2O5	mg/kg	22±2.2	36±3.6
Movable K2O	mg/kg	383±38	411±41
Movable Zn	mg/kg	1.16±0.11	1.41±0.11
Movable Cu	mg/kg	0.236±0.018	0.261±0.02
Movable Mn	mg/kg	12.1±0.91	17.8±1.33
Movable Co	mg/kg	0.032±0.005	0.027±0.004
Total P_2O5	%	0.16	0.12
Total K_2O	%	1.90	1.98
Total Zn	ppm	88.69	79.90
Total Cu	ppm	59.16	60.42
Total Mn	ppm	0.13	0.13
Total Co	ppm	19.81	16.74
<0,01 mm	%	47.80	40.89
<0,001 mm	%	31.00	22.12
Integral assessment of the soil quality on the content of macro- and micronutrients and other useful elements necessary for the plants			
SQ	-	7.89	7.25
Heavy metal pollution			
V	ppm	99.83	115.35
Cr	ppm	86.48	94.21
Pb	ppm	14.81	19.93
Cu	ppm	59.16	60.42
Ni	ppm	57.17	56.05
As	ppm	8.78	8.19
Total index	-	39.50	42.64

interest in studying polygenetic soils that were formed in agricultural landscapes with long history of economic activity is quite natural. To determine the determined by agro genesis changes in soils traditionally the characteristics of the soil which is in virgin lands are supposed to be used as a standard of comparison. This approach has disadvantages, because if you follow the principle of a single difference and in this case assess the effect of the duration of arable farming, the objects of comparison should be genetically close arable soils.

For a long period of formation of the Chora of Kerkinitis land use and land management practices were evolving. After the initial period of the occupation of this region by the Greek colonists, when land resources were abundant which allowed using long-fallow farming system, the stage of regulated land use came due to the consolidation of land plots among the civilian community members. This stage could come from the beginning of the third-fourth quarter of the 4^{th} c. BC with transfer of land management traditions from Chersonese. Within the system of strictly ordered ancient land management and due to the increasing demand for the commodity nature of crop growing the intensity of agricultural influences on soil, of course, increased. Explanation of how the soil is still able to keep the evidence although long agrogenic effects in ancient times but incompatible with the pressure of modern agricultural technologies, comes down to the fact that even a slight but long-term and simultaneously repeated influence leads to an increase in the amplitude of fluctuations and deregulation of the system and is capable of leading to the loss of soil system stability at a certain moment.

When comparing the major agrochemical and agro-ecological indicators of arable layer of carbonate Chernozems (Table 1), the continually plowed land which is localized in the ancient agricultural area at Kerkinitis (p 53) is different from the soil which was first plowed in the 21th century, by being more carbonated, having lower content of fines in grain-size distribution, fines being less enriched with organic substance which is reflected in more lightened color of the soil as well as greater degree of mobility of microelements at a slightly lower content of their gross forms.

Using previous findings (Lisetskii *et al*., 2015) on the qualitative composition of organic substance the continually plowed land near Yevpatoria (p 19), a number of peculiarities should be noted: in the alkaline medium with low content of humus it is characterized as a purely humate type (Cha: Cfa = 2.1), it is characterized by high nitrogen enrichment and high content of nonhydrolyzed residue (66%). Due to the imbalance in the production process (removal of nutrients) and management of soil fertility reproduction (fertilizer and ameliorants treatment) continually plowed land is slightly inferior to modern arable land by content of macro-and micronutrients as well as useful elements (SQ) required for plants.

A slight excess of the value of total index of heavy metal pollution of continually plowed land compared to newly cultivated soil and the fact that not all six but a number of elements forming the decreasing series: V>Cr>pb>Cu contaminate the soil in the area of the ancient polis may indicate a lack of (or irregularity) applications of agro-technological methods that can alter the geochemistry of the arable soil (ash fertilizer, manure, use of irrigation) significantly.

The most informative indicators of agro genesis were chosen out of 90 indicators of macro-and microelements content, physicochemical properties of the soil as well as relations and ratios calculated on the basis of these data. With the help of iterative calculations with the test statistic W for an increasingly shrinking set of indicators as a result of successive elimination with minimal differences between the objects we were able to identify the indicators that characterize agro-technogenic differences between the studied soils most substantially and accurately (Table 2). Statistical calculations based on 17 indicators that can be regarded as indicators of agro genesis duration (Table 2) showed that the difference between the linked samples is statistically significant at the significance level $\beta = 0.01$ (error probability $p<0.01$).

To check the resulting output we used the comparison of continually plowed land from the section p 53 and its territorial analogue (p 19, the data of which have been published before (Lisetskii *et al*., 2015). Calculations with test W for two independent samples in accordance with 25 common physical, chemical and geochemical indicators showed that the differences between neighboring continually plowed land are not statistically provable.

The share of natural sand (particles >0.01 mm) in continually plowed land is apparently bigger due to prolonged effect of weathering that defined the most blowing fine particles. The so-called "technological" dusting is an indispensable companion of processing (plowing or cultivation) of dry soil in particular that is regularly (every 3-4 years) observed in the practice of farming in the steppe zone. The review of a large number of works aimed at studying agro genetic transformation of soils of the steppe zone shows the following features:

Table 2: Statistically valid indicators of duration of agro genesis of calcareous Chernozems

Soil indicators	p 36	p 53
Share of particles >0.01 mm	52.20	59.11
CaCO3	5.98	9.44
CaO, %	5.22	2.91
Sr, ppm	72.32	88.08
Ka (Sr)*	1.67	2.33
Ba/Sr	7.54	6.03
Ba (MgO)*	0.94	1.22
Ba (MnO)*	1.05	1.46
Movable Mn, mg/kg	12.1	17.8
Pb, ppm	14.81	19.93
Ba (Pb)*	1.73	1.25
Ke	5.69	7.810
Al2O3/(CaO+Na2O+MgO)	1.60	2.49
TiO2/(Al2O3+CaO+K2O)	4.69	5.810
Zr/(Al2O3+CaO+Na2O+K2O)	15.01	18.37
(Fe+MgO+Al2O3)/(Na2O+CaO+K2O)	2.07	2.86
Movable P2O5, mg/kg	22	36.0

*a (E) = C<0.25 mm/Csoil

long cultivated soils have higher water permeability compared to the virgin soils; the depth of spring soaking increases; there is a possibility of autumnal irrigation; "dead" dry horizon disappears; periodically flushing regime forms. This assumes that continually plowed land can obtain the characteristics diagnosing the removal of compositions with very high mobility from tilled horizon if inert elements-witnesses (Zr, Ti, Al) are used with respect to which it is possible to calculate the migration ability of weathering and soil formation products.

It is noteworthy that as compared with newly cultivated soil continually plowed land has bigger value of more dynamic indicator of soil modes-CO_2 carbonates but lower content of more conservative Mg and Ca oxides, i.e., total carbonate.

The ratio of Ba/Sr which generally characterizes leaching, does not show that continually plowed land has a greater degree of manifestation of this process due to the high content of strontium that is geochemically combined with calcium carbonate. As noted above, the phenomenon of accumulation of Sr and V in the top soil occurs upon evaporation barrier in more arid environment: in this case continually plowed land has higher content of both Sr and V-by 22 and 16% respectively.

However, the results of active process of leaching prove the differences of the coefficient of elution Ke (Liu *et al*., 2009): removal of oxides of Ca and Mg from cultivated layer of continually plowed land occurs more actively. Geochemical indicator of weathering processes suggests a more active (by 1.6 times) flow from cultivated soil. As for continually plowed land higher values of a number of geochemical indicators that reflect the results in the removal of base cations (Ca, Mg, Na, K) into soil solutions are convincing indicators of influence of arable farming duration on agrogenic transformation of soil system. The special study of chemical composition of fine fractions of continually plowed land excluding sand fraction (>0.05 mm) showed that in comparison with fine soil they were enriched with calcium by 2.5 times, sodium 2 times, magnesium-1.3 times. For comparison in newly cultivated soil fraction <0.25 mm contains slightly less Ca and Mg (by 6-7%) than soil does in general but it contains more Na (by 1.7 times).

Compared with the whole mass of fine soil (particles <1 mm) in size fractions from silt to medium sand (<0.25 mm) evolutionarily significant evidence of continually plowed land history manifests more clearly: out of eight different values of the accumulation coefficient (Ka (E)) the most impressive enrichment of colloids, silt and silt fractions is manifested by such elements as Sr, Mn, Pb, Mg (Table 2). Thus, the processes of weathering take place in continually plowed land and newly cultivated soils at different levels of structural organization of soil system.

CONCLUSION

The soils in the ancient agricultural areas not so much by the intensity of agricultural loads as by their regular recurrence for a long time can record and store in some of their properties evolutionarily significant evidence of agrogenic transformations that are not "deleted" even for a subsequent period of intensive agriculture. For calcareous Chernozems of Crimea steppe zone which differ in the duration of arable farming, we have 17 statistically valid and the most informative major indicators of agro genesis duration chosen from the total number of 90 tested indicators (the content of macro-and microelements, physicochemical properties of soils and biogeochemical factors). Indicators of centuries-long duration of calcareous Chernozems agrogenesis reflect the processes of weathering, leaching, secondary carbonating, the accumulation of a number of elements and dehumification in fine part of the soil. The established indicators of agro genesis duration allow us to apply scientific methods and to reason the perimeter of the centuries-long use of arable land for the longest period of the rural district of ancient Kerkinitis functioning for the period of 6th-2nd BC).

ACKNOWLEDGEMENTS

The reported study was partially supported by Russian Foundation for Humanities. Project "Geoarchaeology monuments and ancient agricultural landscapes of Crimea" No 15-31-10136.

REFERENCES

Burachkov, P., 1881. Experience of agreement of inscriptions discovered in Chersonese with the countryside nature and preserved by the ancient writers information related to the time of the wars of Diophantus, commander Mithridates with the Scythians. Notes Odessa Soc. Hist. Antiquities, 12: 222-248.

Homburg, J.A. and J.A. Sandor, 2011. Anthropogenic effects on soil quality of ancient agricultural systems of the American Southwest. Catena, 85: 144-154.

Jusoh, A., Y. Sauman, N.H.S.N. Abdul Rahman and Z. Ramli, 2012. Scientific analysis of samples of some artefacts Metal Age in Malaysia. Social Sci., 7: 772-777.

Kutaysov, V.?., 1990. The Ancient City Kerkinitis. Naukova Dumka, Kiev, Ukraine,.

Kutaysov, V., 2004. Kerkinitis in Antiquity. Corvin Press, Kiev, Ukraine,.

Kutaysov, V., 2013. The Antique Polis of Kerkinitis. Simferopol Publishing House, Ulaanbaatar, Mongolia,.

Lisetskii, F., V.F. Stolba and O. Marinin, 2015. Indicators of agricultural soil genesis under varying conditions of land use, Steppe Crimea. Geodermal, 239: 304-316.

Lisetskii, F.N. and M.E. Rodionova, 2012. Soil and landscape changes in ancient agricultural areas (exemplified by antique Olbia). Geography Nat. Resour., 33: 327-335.

Lisetskii, F.N., 2012. Soil reproduction in steppe ecosystems of different ages. Contemp. Prob. Ecol., 5: 580-588.

Lisetskii, F.N., V.F. Stolba, E.I. Ergina, M.E. Rodionova and E.A. Terekhin, 2012. Post-agrogenic evolution of soils in ancient Greek land use areas in the Herakleian Peninsula, southwestern Crimea. Holocene, 23: 504-514.

Liu, G., L. Li, L. Wu, G. Wang and Z. Zhou et al., 2009. Determination of soil loss tolerance of an entisol in Southwest China. Soil Sci. Soc. Am. J., 73: 412-417.

Smekalova, T.N., B.W. Bevan, A.V. Chudin and A.S. Garipov, 2015. The discovery of an ancient greek vineyard. Archaeol. Prospection, 23: 140-159.