ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

A New Approach to Dating the Fallow Lands in Old-Cultivated Areas of the Steppe Zone.

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ABSTRACT

We have determined the landing rate of limestone into soil on uneven-aged surfaces (mound and deposits) in the ancient agricultural steppe region of the Northern Black Sea Region (chora of Kerkinitis) with well represented carbonate soils. To make reasonable choices of objects of study we used an integrated approach, which includes historical and cartographic analysis, GIS-technology remote sensing and field GPS-referencing. It is shown that the most objective factor that can be used for dating long-fallow lands is the mean volume of subsurface rocks based on a large sample method (30 or more measurements).
Keywords: ancient agriculture, uneven-aged deposits, soil rockiness, deposits dating, Crimea

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ISSN: 0975-8585

INTRODUCTION

Socio-economic factors may lead to a reduction in the proportion of arable land and the formation of fallow land. It is also associated with the emerging necessity of ecological rehabilitation of degraded lands and their conservation. Deposits in geobotanical sense [1] are such ecosystems that once (a year ago) have been used for cropping, but were withdrawn from operation and are currently developed mainly under the influence of natural processes. In scientific sense, the problem connected with the study of the functioning features of postagrogenic ecosystems as well as estimation of the soil renaturation and vegetation rate is the focus of scientists of many countries [e.g., 2-6], including Russia [e.g., 7-9.]. In this regard, territories with long-term ancient arable agriculture, which have post-ancient and uneven-aged deposits of XIX-XX centuries, are of particular interest. The idea of economic development of the North-Western Crimea in antiquity has changed significantly in recent years, which is due to both the discovery of a significant number of new settlements of farmers and ranchers, and the registration of an unusually large number of mounds [10-12].

METHODS

Investigations were carried out in Yevpatoria district, Republic of Crimea, where the uneven-aged deposits and (for comparison) the top of a low (1.5 m) mound (Fig.) were sorted out similar landscape conditions. The choice of dated mound as a key object is based on the necessity to have a time frame for other accounting plots. An integrated approach, which includes historical and cartographic analysis, GIS-technology remote sensing and field GPS-referencing, was used to make reasonable choices of objects of study. The source materials were the topographic map 1:25 000 (survey of 1957)), aerial survey of 1973 and satellite images of 1974-2000, (Landsat (2,4,5,7), as well as MSS, TM and ETM+ units.

According to the relief conditions, the investigated territory is a marine plain at an altitude of 12 to 18 m. Background soils - Petrocalcic Chernozem (WRB). The northern part of the watershed of lake Sasyk is geologically a motley combination of Neogene rocks.

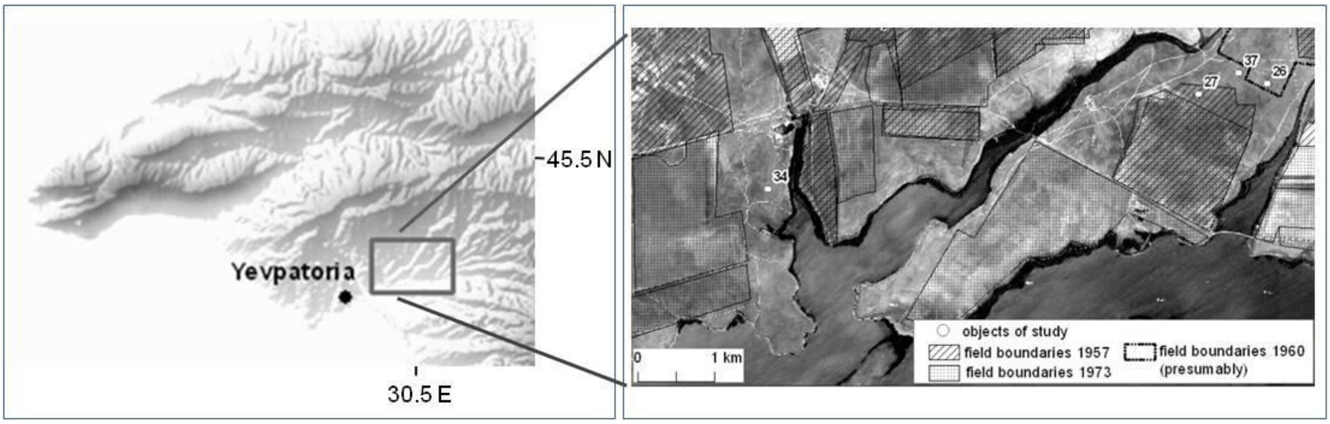

Fig: Land-use boundaries and location of accounting plots in Yevpatoria district, Republic of Crimea. (Satellite image WorldView2, 2012 (Maps.Yandex)).

The surface (especially if the land ever plowed) is covered with angular clastic sedimentary rocks, which often have a size of 1-10 mm (gruss), but there is also larger gravel (10-100 mm). This compact limestones Sarmatian stage (the lower tier of the Upper Miocene Neogene system). The original color of the limestone is very pale brown (10 YR 8/3) or pink (7.5 YR 8/4), all of them are covered with crustose lichen (Xanthoria parietina). Nearly 30-35 stones with a diameter of 10 cm, which had been partially visible on the surface and certainly dipped into the soil for a long time, were taken from all accounting plots. In the field environment, the mass of stones was measured on scales accurately to within 1 g. Due to individual and often complex shape of each stone, its volume was evaluated by weight of water it displaces in the measuring vessel with a diameter of 11 cm. Processing of data on the degree of stone landing in the soil, both in terms of depth and volume, allowed us to decompose the total variation into the dispersion of variants and mistakes, to assess the significance of the F-test factors as well as the significance of differences between the averages by least significant difference (LSD).

Main part

In these soil and climatic conditions, the number of plant species per $1m^2$ is 17 in a virgin land, while there are 12-14 species within uneven-aged deposits (Table 1). At the same time, with an increase in age of the deposit, where there is a gradual transition from a rhizome-grass to the bunchgrass stage, the proportion of steppe grasses may reduce (this, in particular, is reflected by feather grass succession stage, which lasts no more than 50 years, as the pl. 27 shows).

[The ratio of steppe graminoids, which with the increase of the fallowing period pass from the rhizome gramineous to turf gramineous stage of demutation, is the largest in the post-antique fallow lands].

Table 1: Characteristic of accounting plots within uneven-aged deposits (*chora* of Kerkinitis)

No. plots	Plant association (May)	TPC	N	Main species
37	Mixed herbs	70	14(1)	*Poa, Achillea millefolium*
26	Sagebrush and sheep fescue	60	13(3)	*Artemisia taurica, Festuca valesiaca, Poa,* lichens
34	Graminoid-grasses	70	14(4)	*Festuca valesiaca, Artemisia taurica, Poa, Agropyron pectinatum*
27	Feather grass	70	14(4)	*Stipa capillata, Poa, Stipa lessingiana*

Abbreviations: N — Number of plant species per 1 $м^2$; (incl. graminoids); TPC — total projective cover, %.

As indicated earlier [13], livestock farming prevailed over agriculture in the steppes of the Black Sea until the 1830. By the end of the nineteenth century a temporal parity was established in arable territories and natural areas, and by 1915 the possible plowing limit was reached and natural vegetation has been localized in 10% of the land. The course towards large-scale development of virgin and fallow lands adopted in the USSR has resulted in the cultivation of land unsuitable for agriculture in 1954-1960. In the XX century in Russia nearly 70 mil. ha lands were withdrawn from agricultural use, 2/3 of them due to the socio-economic processes of the second half of 1980 - 90s. [7].

On the Crimean peninsula the proportion of soil on dense rocks and their diluvium is 33.7% of total area. Assessment of the impact of gritty consistence on the decrease in crops harvest allowed establishing [14] the correction factor for rockiness to soil quality: for weakly, medium and highly lithogenic soils - 0.85, 0.70 and 0.40, respectively, and the use of last two soil types of soils as arable is impractical. It is reasonable to use low-profitable lands as a fodder land on a regular basis [15]. In addition to socio-economic problems and the impact of rockiness on the level of soil fertility, the extension of area of deposits is due to another important reason, namely, worse technological properties of stony soils, which leads to higher costs per unit. Landing of stones into soil over time masks its potential low-profitability as arable land, which may lead to periodic attempts at plowing long-term deposits.

Rates of local physical and chemical weathering of rocks are defined by both the combined effect of abiotic factors and aggressive vegetation colonization [16]. The rockiness in steppe conditions creates a special mosaic structure of hydrothermal conditions at the local level: white limestone increase albedo initially after plowing until the formation of crustose lichens, and further the desert varnish. The deeper the stones dip into the soil, the more water is retained by the soil under these stones.

The screening effect of stones prevents the pedogenesis directly under them. A high insect activity (colonies of Myrmica rubra, Scolopendra cingulata, etc..) was usually noted in the contact zone of the bottom surface of the stone and soil. There is a dominant growth of soil down around the stones in pedogenesis, and a definite role is played by factors that promote the growth of the soil up (mineral fallout of global aerosols, dissolved solids of atmospheric precipitations, aeolian supply). In addition to these factors, the role of biota is very significant. According to our estimates, the ants (Myrmica rubra) annually throw onto the surface nearly 1.1 t/ha of fine earth, which has a smaller size (less than 0.5 mm) than the soil of their habitat. Earthworms in virgin steppe soils can move nearly 240 t/ha of the material from underhumus horizons during pedogenesis. Although there was a bioturbation under the stones, the soil density was 0.12 g/cm3 more than the density of deposits at the same depth due to formation of structure by root systems. These features are very similar to the formation process of young soils, in which the loosening of the A horizon compared to the soil-forming rock occurs due to the structure formation, the activity of soil biota, especially earthworms and plant roots [17].

The age of mound 37 was evaluated by comparing the archaeological and pedohronological data. Research of pecular low mounds in Crimea, which consist of small and medium stones and a small amount of soil from the archaeological excavations of the mound of this type [12], allowed determining the time a stone tomb inside it was created (IV c. BC.). A fragment of Sinop amphora, which dates back to the latter half of IV c. BC, was discovered at a depth of 19 cm near the predatory excavation at the top of pl. 37. According to the depth of soil on the top of the mound (A+AB=20+15 cm) it is at least 2070 years old after a model [18]. There is a settlement of II c. BC next to the mound, where the depth of humus horizon (A+AB) on the vegetable soil was $X \pm t_{05}\ S_x = 350.3 \pm 6.4$ mm (n=23). Thus, we can conclude that the mound 37 refers to the ancient era and has never been plowed.

Lands of the studied area were involved in agricultural development in the formation period of chora of Kerkinitis (6 c. BC - 3 c. AD). The investigation of a former vineyard (pl. 34) near the ancient settlement (sec. half of IV c. - ca 270 yr BC) revealed the plantage walls and series of stones up to 60 cm. Study of soil and genetic features in the trench and the results of chemico-analytical determinations of soil have shown that the plot is a post-antique deposit. The plot (pl. 26), where low (up to 25 cm) earth mounds of the ancient land survey system has been found during geoarchaeological studies, was referred to the same type of deposit. According to maps and aerial photographs, the most younger deposit is pl. 27. In 1957 there was an arable land for field crops, which became fallow in the early 60th of XX c. (Fig.). Remote sensing analysis showed that plots 26 and 27 are in the same contour with traces of ancient land survey (land boundaries pass from NE to SW through 48-52 m).

Long-term arable farming causes abrasion of stones by farming implements in rank soil of plough horizon (usually up to 20-22 cm). When abandoning the arable lands, the depth of stone landing depends on the duration of a drive. The use of deposits (plots 26, 27) for sheep grazing, and a plot 34 for horse grazing, could result in turning some stones. The recent cases were revealed by the presence of crustose lichens (and/or desert varnish film) on one side of the stones. Methodologically, it was important to determine whether the mass of stones affects the rate of landing of the stone. According to average readings (n=150), the mass of stones selected from the soil surface averaged 268 g (plots 223-333 g), with a total height of stones averaging 50 mm (39-70 mm) the depth of stone landing varied on different plots. The differences between plots on the average volume of the whole stone were within 0.106-0.176 dm^3 (average - 0.138 dm^3).

Analysis of the results (Table 2) showed that the absolute parameters of intrasoil characteristics of stones most accurately diagnose the dependence on the age of a deposit rather than calculated landing proportion of stones by height and volume. Long-time average annual rate of stone landing (plot 37) is 2.5 mm/100 yr. Using the age of the deposit as a criterion for estimating the information value of those characteristics of stones that can be identified in the field, it was found that a more simple estimate of the depth of stone landing in the soil is behind a method for determining the intrasoil volume of stone. This is primarily due to a complex form of limestone debris cover, which is recessed into the ground.

Table 2: Main characteristics of stone samples ($X \pm t_{05}\ S_x$) on the surface of the accounting plots

Age of succession, years	Depth of stone landing, mm	Proportion of stone landing by height, %	Stone intrasoil volume, $10^3 \cdot dm^3$	Proportion of stone landing by volume, %
Ab. 2400 (37)	59±7.5	80.4±2.6	137.2±17.4	78.2±2.3
ab. 2100 (26)	39±3.0	79.9±2.9	104.6±18.3	78.8±2.9
ab. 2300 (34)	33±4.9	72.6±4.8	98.5±16.4	72.2±2.8
53 (27)	32±3.4	77.7±2.7	69.5±10.5	65.8±4.9
Average	41	77	102	74

With numerous treatments of deposits, some stones can retain evidence of their stay on the surface until the last stages of treatment. The degree of uniformity of the empirical data is minimum for the plot 27 (according to dipping proportion of stones by volume), which suggests the presence of a prehistory of such land plot (an earlier stage of a drive).

Pairwise comparison of average depths of stone landing showed that the mound (pl. 37) has differences (by LSD (0.05)) with all the deposits, but this difference is negligible. And the comparison of average intrasoil volume of stone showed that the plot 37 (mound) and a semicentennial deposit (pl. 27) significantly differ (by LSD (0.05)) from all the variants, and only the long-fallow plots (plots 26 and 34) have no significant differences.

CONCLUSION

Determination of the age of deposits may be based on a combination of land cadastre, cartographic and remote sensing data. However, long-fallow land and those which have been subjected to repeated transformation, may be dated as proposed by the authors, if the deposits have been formed on the surface stony soils (stones occur at depths of 0-30 cm) or postagrogenic soils have at least a minimal degree of stoniness (> 5 -10% of surface coverage). The most objective factor that can be used for dating uneven-aged lands is the mean volume of subsurface rocks based on a large sample method (30 or more measurements). The method has heuristic potential because the analysis of the dependence of the average value of the intrasoil volume of stones on the duration of a drive allows revealing the heterochronical objects with latent periods of agricultural development.

SUMMARY

Using the age of the deposit as a criterion for estimating the information value of those characteristics of stones that can be identified in the field, it was found that a more simple estimate of the depth of stone landing in the soil is behind a method for determining the intrasoil volume of stone. This characteristic allows dating the long-fallow lands on the surface-stony soils during the formation of a large sample of data ($n \geq 30$).
Results were obtained in the framework of the national tasks of the Ministry of education and science of the Russian Federation No 5.78.2014/K

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