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# SOIL FORMATION IN THE MEDITERRANEAN TYPE OF CLIMATE, SOUTH COST OF THE CRIMEA

**Introduction.** Considerable differences in the reflection of the soil forming process require a differentiated approach in the use of humus horizon rates as one of the standard of soil conservation and land rehabilitation. The natural formation rate for new soil is between 0.1 to 10 tonne/hectare/year. With such a very slow rate of soil formation, any regular soil loss of more than 1 t/ha/yr can be considered as irreversible within a time span of 50-100 years. Losses of 20 to 40 t/ha in individual storms, that may happen once every two or three years, are measured regularly with losses of more than 100 t/ha in extreme events. Soil erosion by water is very aggressive in Southern Europe [5] and also in a mountain part of Crimean Peninsula of Ukraine where bioclimatic, topographic and human pressures occured intensively enough and during the significant period of time, since the Greek colonization territory in the Northern Black Sea coastal steppes.

**Objects, methods and conditions of research.** In a belt of subtropical soil formation of the Southern Europe and Southern coast of the Crimea (Ukraine) are typical cinnamon soils of evergreen xerophytic woods and bushes with the significant maintenance humus (7-10 %, and on occassion 13 %), big contents of carbonates on all profile. Formation of such landscapes is appreciably caused by a climatic barrier role of the Main ridge (Yajla) with heights up to 1200-1500 m. On Crimean Mountains passes one at the northern border of the subtropical (sub-Mediterranean) zone. Mediterranean climate – subhumid mesothermal with dry summer. In the region of the mountainous Crimea two districts have been distinguished: the Main mountain-meadow-forest Range and Crimean South Coast of the sub-Mediterranean type. Climate here – sub-Mediterranean hot arid. Long-term climatic data is as follows: mean annual temperature – 13.0 °C; mean July – 24.0°; mean January +4.0°; sum of active temperature more 10° – 3940°. Mean annual precipitation reached 550 mm. The vegetation is dominated by dry juniper-oak forests and shibliaks of the Mediterranean type. In western part of the South Coast of the Crimea are characteristic juniper-oak low-trunk forests with an eternal green underbrush. Existence of the evergreen plants is likened western part of Crimean South Coast with communities of maquis in the Mediterranean countries. In western Mediterranean forests and scrubs, primary production can vary largely between 77 and 1500 $g \cdot m^{-2} \cdot year^{-1}$ [2]. Under Crimean forests production averaged 370-390 (under pine (*Pinus Pallasiana Lamb.*)) and 520-570 $g \cdot m^{-2} \cdot year^{-1}$ (under oak (*Quercus pubescens Willd*)) [8].

Cinnamon soils are typical and zonal type of the Crimean South Coast and particularly in south-western part of the mountainous area (up to height of 400-600 m above sea level). Rocks forming soils, on which were generated cinnamon soils are very various: limestones, marlstones, pudding rocks, slatestones, sandstones, their clay-rubbish eluvium and mixed deluvium. Total square of cinnamonic mountainous soils of dry forests and shibliaks come to 48500 ha, including cinnamonic soils on residual deposits and deluvium of solid rocks - 67 %.

**Material and methods of research.** Chronofunctions (pedochronological data) are developed by results of soil study on archaeological monuments to the East-European plain [9].

The pedological investigations at Crimea are based on the identification of soil morphology in conformity with archaeological age of substratum (table 1).

***1. Principal objects of the study area***

| *Geographic region* | *Object of study* | *Soil* | *Depth, cm* | *Humus, %* |
|---|---|---|---|---|
| Cape of Ai-Todor, altitude 77 m | Upper defense wall of Roman fortress Haraks (I c. B.C. - III c. A.C.) | Cinnamonic soil: – on eluvium's carbonate rock; – on platy parting of limestone | 0-10<br>10-27<br><br>0-19 | 7.0<br>6.0<br><br>10.1 |
| 8 kilometers west of the town of Sudak | Kutlak, remains of settlements I c. A.C. | Cinnamonic soil on mechanical mix of loam and backsoils | 0-30 | 7.7 |
| Geraklejsky peninsula in the south-west city of Sevastopol | Gerakly, remains of settlements III c. A.C. | Cinnamonic soil on eluvium's limestones (ruins of stone fencings from land-surveying) | 0.26 | 5.5 |
| Cape of Ai-Todor, buttress Monastyr-Burun | Ruins of Fedor Tiron's Church X c. | Red-cinnamonic soil on thick limestone of upper Jurassic | 0-6<br>6-15.5 | 2.2<br>1.4 |
| Eastern Gursuf, Cape of Plaka (magmatic diapir) | Defense wall X c. | Cinnamonic soil on eluvium's carbonate and rocks | 0-13<br>13-27 | 4.6<br>- |
| Gursuf Amphitheat-re, butte Krasniy Kamen, altitude 500 m | Defense wall XI c. | Cinnamonic soil on rock debris of marble limestone | 0-8<br>8-16 | 8.0<br>- |
| Be west of t. Yalta - butte Krestovaja, altitude 255 m | Defense wall XIV-XV cc. | Cinnamonic soil on calcareous debris | 0-5.5<br>5.5-14 | 8.4<br>8.4 |
| 3 km to the north of Gurzuf, from the village Krasnokamenka | Gelin-Kaya, castle ruins XV c. (Issar) | Cinnamonic soil on metamorphic limestone of reddish color | 0-15.8 | 8,0 |
| South foot of Demerdzhi-Jaila, altitude 400 m | Fortress Funa, was destroyed in 1475 | Cinnamonic soil on calcareous debris | H, 0-18<br>Hp, 18-31 | 6.4<br><br>5.4 |

For the synthesis of the conditions of warm and moisture provision of zone community of soils and vegetations the bioenergetics' approach is used (according to Volobuev [6]), supposing the conduct of counting up of energy outlay on soil formation (Q, $MJ \cdot m^{-2} \cdot yr^{-1}$) by the following formula:

$$Q = 41.87(R \cdot e^{-18.8\frac{R^{0.73}}{P}}), \quad (1)$$

where R is the radiation balance, $kcal \cdot cm^{-2} \cdot yr^{-1}$ and P is the total precipitation, mm.

**Results.** Energy outlay on soil formation (Q), as one of very important parameters of the mathematical model of the soil-forming process [10], averaged 1270 $MJ \cdot m^{-2} \cdot yr^{-1}$

for conditions of the Crimean South Coast (by formula (1)). In view of in the Crimea Mountains with raising on every 100 m yearly average temperature decreased on 0.69°, but precipitation increased, the energy outlay on soil formation on height 500 m slightly increased to 1330 $MJ \cdot m^{-2} \cdot yr^{-1}$. It is limits of area cinnamonic soils.

Process of soil formation directly is connected with specificity of a hydro-thermal mode which is formed in the winter – damp rather warm. To this period there is an intensive weathering with formation of secondary clay minerals hydromicaceous montmorillonitic-illitic composition. In the summer delay of process of a mineralization promotes polymerization and humification – to preservation humus substances in soils.

Following set of genetic horizons has cinnamon typical soils on new (substantive-genetic) soil classification of the Russia: AU-BM-BCA-Cca and Hd-H-Hp-Ph-P on soil classification of the Ukraine. Full Holocene soils (age of 10-12 thousand years) have the general capacity humus thicknesses (H+Hp) 70-80 cm, at low-power soils – 40-50 cm. Thickness of the humus accumulative horizon makes 5-20 cm, it has brown or brown-grey painting (very dark grayish brown in the top horizon and dark (reddish) brown below (10 YR 3/2 and 10 YR 3/3 (5 YR 3/2) (Munsell standard color names), granular-powdery structure. Cinnamon soils on products of weathering limestones have a reddish-brown shade.

Granulometric composition of the cinnamon soils varies from middle-loamy (particles <0,01 mm of 30-45 %) up to is heavy-loamy and middle-clay. Their characteristic feature is presence of skeletal particles in the form of rubble and stones which quantity increases downwards on a profile. Reaction of a soil solution for the top horizon more often neutral (pH=6,8-7,0), from top to bottom – alkalescent (pH=7,5-7,7). The complex absorbing is sated basically by calcium (80-90 % of the sum of the bases).

Humus horizon (AU) thickness in 16-19 cm was formed on thick rocks and 20-22 cm on calcareous rock debris for 1600-1740 years of soil development. Humus accumulation mainly depended on tipes of parent rock: by 800 yr reorganization of the calcareous residual deposits accumulated 8 %, in following contents increased slightly. The values of humus contents for soils with complete profile (Holocene age) were high, varying between 7 and 9 %, but for agrolandscapes conditions (vineyards, tobacco, essentially-oil-producing crops) contents varied between 2.0 and 3.8 %.

To soil-chronological researches unique monument Haraks – the strengthened settlement which is connected with Roman garrison put in Chersonese is especially valuable. The site of ancient fortress is fenced by a wall partially combined from enormous and rough blocks, belonged Tavric strengthening which has entered into system of the Roman border fortifications. Walls existed in I-IV centuries A.D. Soil formation after 17 centuries restoration of soil properties (table 2) describe locations covered with the primary mountainous Crimea's flora (*Quercus pubescens, Pistacia mutica, Juniperus excelsa, Ruscus ponticus*).

Numerous investigators have depicted the relationship between soil properties and time (soil chronofunctions) as being exponential [3]. We found that the development of the cinnamonic soils followed an exponential dependence with time. Taking into consideration the dependence of the thickness of humus horizon ($H_t$, mm) of the main soils in the Eastern European Plain on heat and moisture, the establishment of vegetation, time and compositation of the parent rocks, we will get the model [4]

***2. Indicators of the cinnamonic soils a 1600-1700-year-old on defense walls of Roman fortress Haraks (Cape of Ai-Todor)***

| Soil indicators | Upper wall | | | Lower ("tavric") wall | |
|---|---|---|---|---|---|
| | Horizon and depth (cm) | | | Horizon and depth, cm | |
| | Hd, 0-5 | H, 5-16 | Hp, 16-31 | H, 0-7.5 | Hp, 7.5-16 |
| Color (by Munsel) | | | | | |
| dry | 10YR3/2 | 10YR3/2.5 | 10YR4/2 | 5YR3/2 | 5YR3/3 |
| moist | 7.5YR3/1 | 7.5YR3/2 | 7.5YR3/2 | 7.5YR3/2 | 5YR3/2 |
| Bulk density, $g/cm^3$ | 0.51 | 0.56 | 0.73 | 0.52 | 0.65 |
| Humus, % | 8.5 | | 8.4 | 8.7 | 8.3 |
| $N_{gross}$, % | 0.250 | | 0.246 | 0.908 | |
| C : N | 19.7 | | 19.8 | 5.6 | 5.3 |
| $CaCO_3$, % | 27.07 | | 21.14 | 0 | 0 |
| $Ca^{2+}$, mg/100 g | 18.0 | | 14.0 | 16.0 | 16.0 |

$$H_t = 10.85g(F_f / F_z)^{0.37} e^{0.0044Q}(1 - ke^{-\lambda t}), \quad (2)$$

where g – coefficient, which reflect granulometric composition (0.72÷1.40); F – annual production of vegetation, t $ha^{-1}$ $yr^{-1}$: $F_f$ – actual; $F_z$ – zonal; Q – annual outlay of energy on soil formation; t – time, year; k, λ – coefficients, which were received from pedochronological facts.

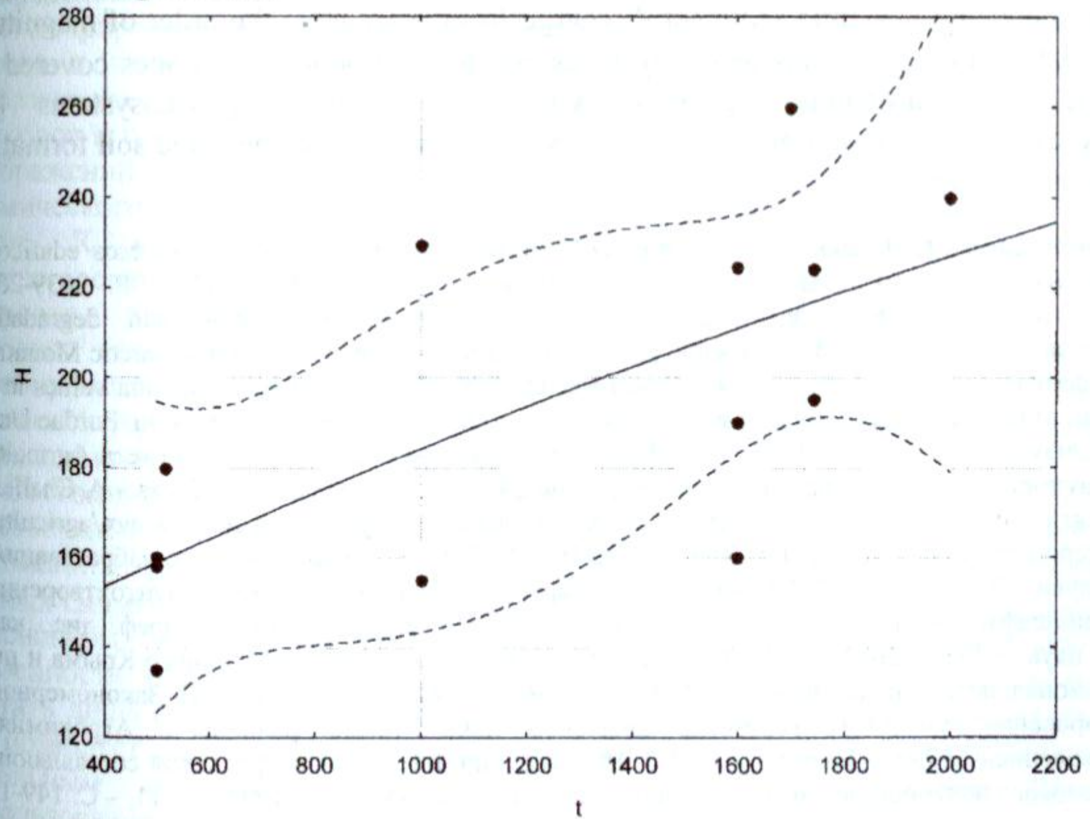


***Figure. Dependence of humus horizon thickness (H) of the cinnamon soils with time (t)***

The rate of soil formation is estimated from the depth of soil horizons and the years of formation. It is supposed [1], that rate of soil formation in a small degree depends on degradation, as the soil structure (apparently, in conditions of natural soil formation) can "migrate", not undergoing essential changes on genetic horizons. However, soils which are formed on dense rocks, such as in particular, cinnamon soils, are limited by a layer for the present to not subject processes of weathering. Earlier [7] the equation describing dependence of capacity of humus horizon thickness of automorphic cinnamon soils, generated on eluvium and deluvium of the dense rocks, from time was offered:

$$H_t = 365(1 - e^{-0.0007t}). \quad (3)$$

New model describing dependence of humus horizon thickness of the cinnamon soils with time (last 2000 years of Holocene evolution) is graphically presented in figure and its analytical expression looks like:

$$H_t = 400(1 - 0.674e^{-0.00022t}). \quad (4)$$
$$R = 0.683$$

**Conclusions.** The traditional way of definition of "soil loss tolerance", which is connected with getting of average estimation of pedogenesis'es rates during the considerable time interval, leads to involuntary negation of the dependence of humus horizon formation rates from its deepness [4]. Generalization of facts for 13 dating surfaces in zone of Mediterranean climate of Crimean South Coast give according to the above-mentioned model (4) estimation of yearly average increase of humus horizon's thickness at first 2000 years of soil formation is 0.047 mm/year or about 0.6 $t \cdot ha^{-1} \cdot yr^{-1}$. In an interesting that little sediment discharge from erosion (in the order of magnitude of 0.05 to 1 $t \cdot ha^{-1}\ yr^{-1}$) was generally measured to be produced on slopes covered by natural or semi-natural vegetation within Mediterranean geoecosystems [2]. Consequently, below natural vegetation rates of sediment detachment and soil formation regained balance.

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