THE INFLUENCE OF NATURAL HAZARDS ON SOIL DEGRADATION AND AGRO-INDUSTRIAL COMPLEX IN THE CRIMEA

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Under discussion are the data about adverse effects of unfavorable natural phenomena associated with the high temperature regime, low precipitation and strong winds on the soil erosion, the development and formation of crop yield. The state of forest shelterbelts and their ecological significance as well as the role played by forest-ameliorative and soil protection measures are shown in the Republic of Crimea.

Keywords: droughts, soil erosion, forest shelterbelts, agroecology, fertility, yield.

INTRODUCTION

In the Republic of Crimea the soil cover reveals a great diversity however the most extensive soils are southern chernozems. They occupy above 45% of the total territory mainly concentrated in the plain (87%) and piedmont (13%) areas. Chernozems in the plain zone have been developed in conditions of the moisture deficiency under the sod-grass vegetation of dry steppes. Due to the water deficit and the low amount of biomass these soils contain only 3–3.5% of humus accumulated predominantly in the shallow humus horizon [10]. The southern chernozems are intensively used in agriculture, 80% of them are found to be under crops now. The intensive and total land use within the zone, where the moisture is deficient and the sharply expressed continental climate is accompanied by prolonged droughts and strong winds serves as evidence that the soils began to reach the lower limits of productivity. Over the last decades the humus content became decreased from 2.9 to 2.5% on the average; due to accelerating wind and water erosion the soil cover is destructed, the topsoil loss makes up 8.9 t/ha annum and the humus loss is estimated at 0.33 t/ha [5].

The agricultural production is dependent on weather-climatic conditions to a considerable extent, which cannot be affected by human

options, however the peculiar features of this factor must be taken into complete account to avoid its adverse effects on the soil cover with consequent decline in crop yield. Appropriate land management is urgently required to provide the sustainable and efficient agricultural production.

OBJECTS AND METHODS

The objects of research are natural phenomena associated with the high temperature regime, low precipitation and strong winds, what serves as a cause for dust- and snow-storms and droughts; the latter being regularly distributed in the Crimea, have a significant influence on the erosion processes and the formation of crop yield.

The analytical and operative information of Regional Centre of Hydrometeorology, statistical data and reports of the Ministry of Agrarian Policy in the Crimea found an application in the course of these studies with the view of assessing the meteorological conditions and analyzing the effects exerted by them on the soil cover, the growth and development of agricultural crops. The system, complex, retrospective and comparative methods were used for a comprehensive analysis of available information; applicable were also landscape-environmental, agro-ecological and agro-meteorological scientific-methodical approaches, economic-statistical and abstract-logical methods.

RESULTS AND DISCUSSION

The Crimea peninsula is located at the boundary of continental and mediterranian climate types. The small-sized peninsula (about 27 thou km^2) embraces 7 soil-climatic zones to be a region with diverse conditions for the agricultural production [6, 4]. The physiographical position of the Crimea provokes unfavorable weather-climatic factors adversely affecting the environment in some years. Such natural phenomena as strong winds, droughts, dust – and snow storms pose serious hazards at present and threaten with even more dangers in the foreseeable future.

In the Crimea peninsula the north-eastern, south-and north-western winds prevail in a year. In winter the north-eastern winds are dominant and when they are accompanied by arctic air flows there is a

cold snap. In spring the steppe areas of the Crimea are subjected to north-eastern and north-western winds followed by southern winds in the Black Sea coast. Since June to mid-August the northern and north-western winds predominate. The winds at the high velocity are observed at the end of winter and in early spring; in summer the wind velocity becomes decreased. The strong winds or storms (above 15 m/s) are unevenly repeated in different regions of the Crimea. Their duration for a year is usually 10–17 days in the piedmont area, 20–24 days in the southern sea coast, 40 days in the western regions, 12–28 days in central steppe area and 80–85 days in mountains (Fig. 1).

According to statistical data about 30 years are rather dried in the plain zone of the Crimea. As a rule, the droughts occur in the vegetation period during 185–195 days. Very often they are accompanied by dry winds varying from 20–30 days in the northern part of this region to 15 days in the south. The major part of dry winds (60%) tends to blow north-eastwards.

The wind erosion (deflation) is widely spread within the zone of deficient wetting and the low air moisture (southern and central dry steppe). The wind erosion is associated with lowering the soil productivity and sometimes leads to degradation of the soil cover over the huge area of the Crimea. The relief with water runoff along the direction of prevailing winds, the fine particle-size distribution of soils, the low humus content and the fact that the soil surface is bare and not

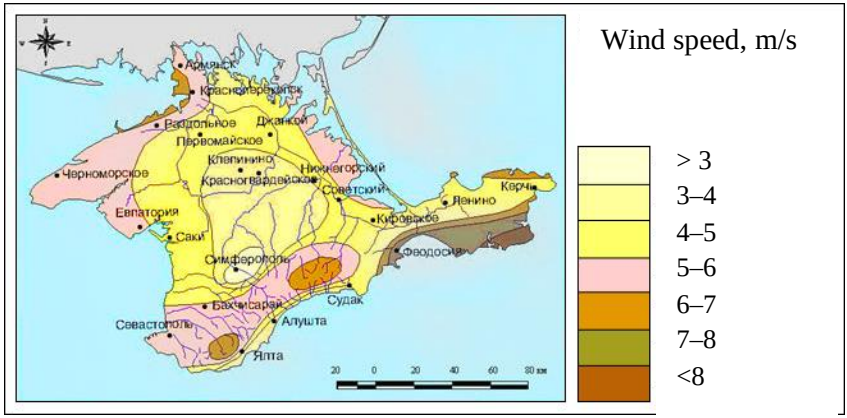

Fig. 1. The schematic map of wind velocity averaged for a year.

covered by vegetation in the most part of time promote increasing the destructive action of winds. The statistical data evidence the increase in the number of days with strong winds blowing from the north-east towards the south-west in the spring period. In the same direction the soil erosion becomes accelerated as well (Fig. 2). About 60% of agricultural lands are subjected to severe erosion. In the Republic of Crimea such natural-agricultural regions as Chernomorsk (54.5 thou ha or 13% of the total area) and Saks (26.7 thou ha or 14% of the total area) suffer from the detrimental effects of the water and wind erosion. The water erosion poses a serious hazard in Chernomorsk (67.7 thou ha or 16%) and Simferopol regions (86.6 thou ha or 30%).

Among the most adverse natural phenomena provoked by wind are dust storms resulting in the fertile topsoil loss. The wind-blown fine soil particles are removed at the velocity of 3–4 m/s, whereas the heavy loamy soils are subjected to the wind influence at the velocity of 6 m/s. The structural soils are more resistant to deflation. The topsoil loss of some millimeters seems to be dangerous for the environment; the hundred to thousand years are required for developing one centimeter of fertile soil depending on the natural-climatic conditions.

At the wind velocity of more than 20 m/s the dust droughts can occur not only in fields which are not covered by vegetation but also in

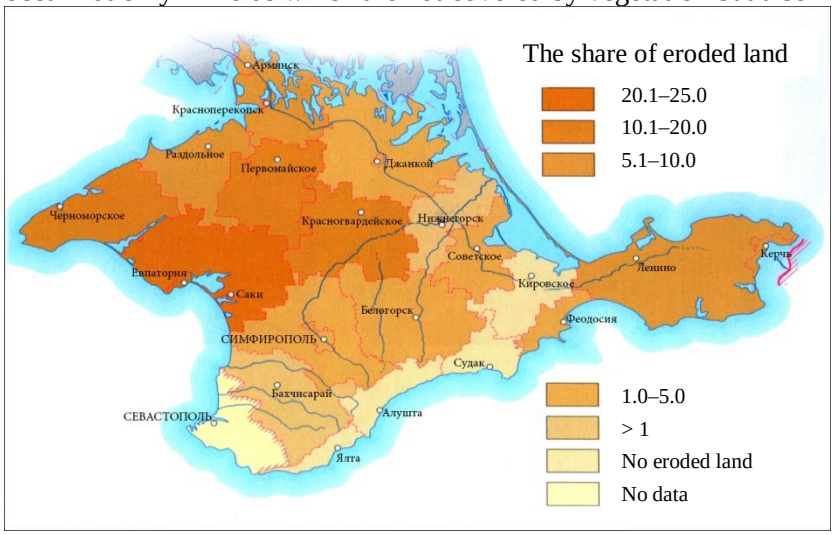

Fig. 2. The eroded lands in the Crimea.

fields occupied by weakly developed seedlings of winter and early summer crops. In this case the topsoil is blown out at a depth of 3 to 10 cm. Due to severe droughts the productive topsoil that has being formed during thousand years is lost for several days. In the Crimea the total loss of fertile lands makes up 143 mln t/yr, the humus loss caused by water and wind erosion averages 11 mln t/yr, the loss of nitrogen – 0.5 mln t/yr, phosphorus – 0.4 mln t/yr and potassium – 7 mln t/yr [1]. Thus, in the humus layer that is lost by erosion the content of nutrients is much higher than that compensated by mineral and organic fertilization.

In the Crimea the stable strong winds of different duration are regular phenomena. The winds at the velocity of 20 m/s take place almost every year but the wind velocity of more than 25 m/s is observed once for 3–5 years [3, 8]. Due to strong winds the dust storms occur in some years. If the productive moisture storage accounts for 20–25 mm in the topsoil the dust droughts appear at the wind velocity of more than 15 m/s, whereas the moisture storage is less than 10 mm the drought can be caused by the wind at the velocity of 8–10 m/s. Severe droughts took place in 1965, 1969, 1972 and 1974. At that time the first efforts were undertaken with the view of developing the irrigation agriculture and soil protective management in the Crimea. In 1965 the winter seedlings were suffered from the dust drought and re-sown at the territory of 45 thousand hectares. The extremely severe and long dust droughts were observed in winter and spring 1969. Due to wind storm at the velocity of 25–27 m/s in January the topsoil loss made up 5–7 cm resulted in complete injury of winter crops. Different regions of the Crimea suffered from the strong north-eastern wind at the velocity of 15–20 m/s during 3–7 days in February 1969. About 100 mln m^3 of the fertile topsoil (in some fields up to 10 cm) were found to be lost; the repeated seeding of winter crops was required at the vast territory of the peninsula (200 thou ha). The difference in yield of grain crops was highly dependent on forest shelterbelts and afforestation degree of arable lands. In Krasnogvardeisk region where the afforestation made up 1.5% the crop injury was estimated at 20.7% but at the territory of the collective farm “Peoples Friendship” and the Crimean experimental station the winter crops remained in a good state because of afforestation in the range from 2.7 to 3.1% of the total area [7]. In 1972 and

1974 the winter crops needed to be repeatedly planted at the territory of 275 and 125 thou ha respectively.

Parallel with dust droughts the snow storms can occur under the influence of strong winds in the Crimea; this natural phenomenon is seldom observed but took place in the north-west of the peninsula in February 2012. The low temperature (–33…–37°C), the wind velocity of 17–21 m/s and the water deficit in the topsoil served as a cause for snow removal together with soil particles from fields into the forest shelterbelts, irrigation canals, roads. The root system of winter crops proved to be exposed and completely injured. The winter injury of crops has been fixed at the territory of 100 thou ha in the Crimea.

The dry winds are hazardous for agriculture to no small degree. They occur in case of combining such meteorological elements as the temperature (>25°C), the relative air moisture (about 30%) and the wind velocity of more than 5 m/s [2]. In the steppe zone of the Crimea the duration of dry winds varies from 3–4 to 6–8 days in the warm period of the year. During the severe droughts the air moisture can be decreased to 7% when the temperature is 40°C and the wind velocity – 9 m/s. In this case the crops in different phases of their development become not only injured but also completely dead. Widespread are spring droughts. In the summer they occur within the vegetation period and in the autumn when the soil is preparing for fall seeding, the latter being observed practically every year in the last decade.

The agricultural crops are repeatedly suffered from droughts at the vast territory of the Crimea. This may be exemplified by the drought occurred in 2002, when the productive moisture storage before the spring vegetation of winter crops was accounted only for 10–19%, the rainfalls could not enrich the soil with water, the average yield of grain crops made up 20.8 centner/ha and the drought-induced damage was estimated at 1.2 milliard roubles. The similar phenomena were observed in 2012 and 2013.

The droughts can also lead to decreasing the grain quality and quantity. In 1994 when the temperature rise was 33°C at the air moisture of 20–25% and the wind velocity of more than 7 m/s during the period of grain forming the grain mass of winter wheat (1000) was accounted for 29–30 g in cropped fields with consequent decline in yield.

120 years ago V.V. Dokuchaev studied the consequences of severe drought in the South of Russia and offered a complex of preventive measures for the steppe conditions. Under his guidance the forest shelterbelts were planted together with a system of ponds and water bodies in Kamennaya Steppe. The first 8 forest shelterbelts appeared in 1897, four years later their amount made up 50.

In the Crimea the first oak forest shelterbelt was created near the settlement Nizhnegorskoe in the last decade of the 19th century. The afforestation was especially intensive in accordance with the objectives formulated in the documents of the USSR Council of Ministers about the creation of forest shelterbelts in steppe regions of the USSR. Within 1949–1960 the forest shelterbelts covered more than 16 thou ha; 25 thou ha have been planted by them at the end of 1980 [1]. In the steppe region the forest shelterbelts are of great ecological importance. They exert the favorable influence on the formation of the microclimate, thus decreasing the wind velocity and promoting the moisture accumulation and storage in soil. The forest shelterbelts along the fields are conducive to increase the air moisture by 7–9% as compared to open fields what creates the conditions so vital for agricultural crops. Thanks to shelterbelts the winter wheat in the dried years, for instance, reveals the good root system and the increase in the amount of grains. During the vegetation period in relatively favorable years when the optimal conditions are created for the plant growth and development and for reproductive organs, the forest shelterbelts contribute to realizing the genetic potential of intensive crop cultivars thus providing the addition yield by 8–10% as compared to that in fields open for winds.

Unfortunately, in the last two decades some agrarian reforms led to decreasing the amount of forest shelterbelts to say nothing of newly created ones. They remained ownerless being subjected to burning for fuel. The forest shelterbelts began to disappear especially in the steppe regions of the Crimea and today they total only 10 thousand hectares, the major part of which is found in the unfavorable state [9].

According to Stadnik (2008) the optimal area covered by forest plantations must account for 3.8–6.2% of lands. In view of this, about 17 thousand hectares are required for creating new forest shelterbelts to protect the cropped fields, gardens and vine-yards, around the water bodies and along the rivers.

The conservation tillage system is an important element of soil management. After dust droughts occurred in the 1960s the experiments have been carried out in the Crimean experimental station with the view of studying different management practices. Under study were soil treatments at different depth, non-moldboard cultivation, deep plowing, subsoil loosening, mulching in a typical nine-field rotation. The subsoil tillage at a depth of 8–10 cm combined with stubble mulching permitted to maintain the moisture in the topsoil, providing rapid and steady seedlings capable to resist strong winds. The stubble and the other plant residues at the soil surface were proved to be a soil-drift control. The stubble in the amount of 100 per square meter decreased the topsoil loss by 57–78%. The mulch consisting of stubble and small soil lumps enabled to increase the wind resistance by 50%. It was also shown that the annual plowing resulted in the deterioration of the most vital physical properties of soils which govern their fertility. The subsurface loosening at a depth of 8–10 cm for winter and 12–14 cm for summer crops led to declining the production expenditures by 25–27%. The scientific-grounded rotations and soil-control practices with crop-residue management for winter crops are urgently required for erosion protection of areas under crops (70%) in the steppe zone of the Crimea. The latter may be promising for application not only of minimum tillage but also no-till. The main principles of this technology are the permanent plant cover, minimal mechanical effects on soil and adapted rotations.

CONCLUSION

The land is the most valuable national property and wealth. When the efforts to promote environmental protection and soil management stopped to be a matter of particular attention by the State, it seems reasonable to notice that the problems of planning, land use and conservation, reduction of field work associated with improving the soil fertility, afforestation and soil protection measures have become very acute in the Crimea. For today, the irrational land use for agricultural purposes, destroying of the rotation structure, accelerating water and wind erosion are reaching the lower limits of land degradation in the steppe zone of the Crimea.

The reconstruction of forest shelterbelts is one of the important problems facing the agricultural production under dried conditions of the Crimea. It allows eliminating the wind erosion and adverse effects of droughts and dry winds with consequent increase in the sustainable development of the agro-industrial complex. As an element of high farming culture the forest shelterbelts should be an integral part of the steppe landscape. The preventive control measures must assume a complex landscape character providing not only the creation of forest shelterbelts but also natural and artificial landscapes, rivers, small streams, ponds and water bodies.

To prevent adverse consequences of unfavorable natural phenomena, it is also very important to improve the existing soil management system with the aim at ensuring the soil protection against wind and water erosion and favorable conditions for water accumulation in the root layer, thus maintaining the natural fertility of soils. The soil protection measures should foresee the minimum treatment actions, the subsoil plowing at a small depth and combination of technological procedures.

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