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KOSTYCHEV'S WORK IN COMBATTING DROUGHT

T. A. Koval'

Today, more than 50 years after the death of P. A. Kostychev, his work in developing scientific soil cultivation has become extremely valuable. Kostychev was responsible for the most advanced agronomical ideas in Russia.

Kostychev was prominent among Russian soil scientists because of his versatile knowledge and ability to synthesize any subject he investigated. His theoretical and practical background in organic and inorganic chemistry enabled him to utilize chemical soil analysis in his investigations. He was also a scholar of microbiology, geobotany, and agronomy.

In his book, Kurs Pochvovedeniya, (A course in soil science) 1885-1886, Kostychev very clearly pointed out that physical properties of soil exert at least as much influence upon plants as do chemical properties. He was first to develop methods of making soil fertile. "The depth of plowing," wrote Kostychev, "the degree and character of mellowing soil, the time and method of using various fertilizers which can increase or decrease chemical processes in the soil, increase or decrease drying or moistening qualities, and aid in regulating the temperature in different parts of the fields can all be best determined by exact information of soils and their characteristics, which only soil science can provide."

Kostychev lived through the drought of 1891 which was the cause of poverty among countless people. Being well acquainted with the history of the chernozem steppes and their climatic and soil characteristics, he gave a scientific explanation for the appearance of droughts on the immense chernozem zones and suggested measures for preventing future crop failures.

Kostychev did not share the view prevailing at that time that crop failures in the chernozem area were due exclusively to the climate

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of the chernozem steppe, and did much work to disprove this viewpoint. He went to all the main soil cultivating regions where crop failures occurred more or less regularly and proved that the reason for the failures was not due so much to the climate as to the peculiarities of the chernozem soil which requires special methods of cultivation.

In his book, O Borbe s zasukhami v chernozemnoy oblasti posredstvom obrabotki polev i nakopleniya na nikh snega, (Combatting drought in chernozem areas by means of field cultivation and snow accumulation), Kostychev indicates the amounts of precipitation falling in chernozem and non-chernozem areas by comparing two typical places, St. Petersburg and Voronezh. Data collected over a 30-year period beginning 1862 showed that annual precipitation in St. Petersburg ranged from 325 to 726 millimeters, and in Voronezh from 362 to 767 millimeters. Kostychev presented this data in the following table:

Table 1

Distribution of precipitation by seasons (in mm.)

	Winter	Spring	Summer	Fall	Annual
St. Petersburg					
Number of days with precipitation	40	34	38	44	156
Precipitation (in mm.)	74	87	180	129	470
Voronezh					
Number of days with precipitation	34	31	30	25	120
Precipitation (in mm.)	133	130	180	138	581

In comparing seasonal precipitation, it is seen that spring and winter precipitation is much heavier in the Voronezh area than in the St. Petersburg area. Harvests in the chernozem steppe zone depend primarily upon spring precipitation; thus, it can be supposed that poor harvests should occur less often in the Voronezh area than in the St. Petersburg area. In reality, the reverse is true. Poor harvests occur more often in Voronezh because soil conditions for water penetration and accumulation are very different in these two places. This deduction by P. A. Kostychev at first seems paradoxical, but it is confirmed by data obtained from various chernozem steppes — Troitska, Voronezh, and Stavropol'. During the course of the year, the amount of precipitation ~~falling~~ at Troitska was 345 millimeters, Voronezh 581, and Stavropol' 727 millimeters.

Kostychev ~~continues~~ added: "If a section of the Troitska steppe were extended into Stavropol' Kray, it would in no way disrupt the usual appearance of the Stavropol' Steppes." This similarity and the monotypic vegetation on uncultivated steppes in three different areas, notwithstanding the great differences in the amount of precipitation, apparently cannot be explained by the amount of precipitation alone. A better explanation is that "all these areas have the same chernozem soil which seems to exert a greater influence upon plants than the precipitation falling in this area."

Many scholars studying the characteristics of wild steppe vegetation conclude that the only grass plants able to exist are those which ripen by the beginning of the summer. From these characteristics, some scholars erroneously assume that grain crops which ripen during the middle or at the end of July cannot be grown here and that, consequently, the southern steppes are not suited for cultivated crops. Leading Russian scholars and the practical experience of steppe soil cultivation have shown this point of view to be incorrect. When a virgin steppe is plowed, the relation of soil to plants is immediately changed. The plowed virgin steppe is very favorable for growing grains, especially varieties of summer wheat. From this, Kostychev inferred that even with the considerable amount of precipitation, as was noted in Stavropol', for example, plants can suffer from loss of water if the soil does not accumulate and preserve moisture. For this reason, in order to prevent plants from being destroyed by drought, the system of soil cultivation used must create soil conditions which will enable a large amount of water to be accumulated and preserved.

Upon reaching this conclusion, Kostychev gives the following instructions. All soils receive water from rain or thawing snow. Water penetrates some soils easily and quickly, and other soils, extremely slowly. Soils with greatest water permeability are those composed of large particles, gravel, or sand, while finely grained, pulverized soil is almost impermeable. Chernozem soils, notes Kostychev, are composed of small particles which can be ground into dust if rubbed together. A similar composition of unplowed land, beaten down and packed by animals, as is found in the chernozem steppes, seems to indicate that rainwater does not penetrate into the soil but runs off into lowlands and gullies. Even with prolonged moistening, water cannot penetrate far into the soil.

In order to provide plants with as much water as possible, chernozem must be made extremely permeable so as to allow all rain water and water from melted snow to soak into the ground.

While studying ground water in chernozem soils, Kostychev pointed out the laws of capillary action of water. In the dry chernozem steppes, capillary action is dangerous, since the quickly drying top layer of soil has innumerable, minute pores which continually bring up water from lower, more moist layers of soil and cause the top layer to become saturated. Kostychev compares this to capillary action in the wick of a kerosene lamp: "The kerosene in the upper part of the wick is burned and must be continually replenished by more kerosene; in the same way, water is evaporated from chernozem in the form of steam and additional water is brought up by capillary action." In order to prevent this wastage of ground water, he suggested cultivating the upper layer of soil, since this destroys capillary action and thus causes moisture to be retained in the top layer of soil.

Kostychev notes the change in ground water content of chernozem steppes at various times during the year. His investigations show that from September through February, soil gradually accumulates moisture. On the other hand, from March through September, the soil slowly dries despite spring and summer rains.

Chernozem soils as a result of their great capacity to hold water cannot be deeply penetrated by either light or very heavy summer rains which are absorbed primarily in the top layer and quickly evaporate under the influence of wind and sun. Moisture accumulated during the winter, the importance of which is so often underestimated in agricultural practice, is especially important.

Thus, the following conclusions can be drawn from the above information on chernozem soil conditions and their relation to moisture accumulation:

1) to be most successful in combatting drought, agricultural practice should provide for the largest possible accumulation of water during the winter.

2) in order that the largest possible amount of rain and snow water permeate the soil instead of running off the surface, the soil must be kept highly permeable.

3) to check or to lessen gradual evaporation of moisture from the top soil layer, the soil must be cultivated so as to prevent escape of water by capillary action.

Kostychev carefully examined these three points of the plan and gave clear and complete answers to the complex and poorly studied problems of practical soil cultivation. He explained in detail the importance of water in plant development and explained scientifically the so-called usable and non-usable soil moisture in plant development. On a mathematical basis, he determined the amount of water needed for a harvest. According to his calculations, a 2.7 acre area having a harvest of 100 pud of grain and 200 pud of hay, or a total of 300 pud of plants, should have no less than 90,000 puds of water.

He also noted that plants found in any soil cannot exhaust the supply of moisture in the soil, since any soil has a definite amount of water which cannot be used by plants, even when there is a dire need for it. The reasons for this phenomenon are as follows. In any soil, water is to be found in porous ground or in the top soil layer. Kostychev pointed out that if a rock, for example, were placed in water, it would be surrounded by a thin layer of water as a result of molecular cohesion. In order to remove the water, a substance which has a greater affinity for water must be put around the rock, as, for example, a dry towel.

Yet, not even a dry towel can absorb all the rock's moisture. Each particle of the soil can, for convenience, be called a rock, even though it is no larger than a speck of dust. In moist soil, each speck of dust, like the rock surrounded by water, is sucked dry by roots, fulfilling the same work as a damp towel. It is obvious that a moist root cannot absorb all the moisture from the top layer; some water will always be left. Experience has shown that plants in different soils stop absorbing water when the water content reaches the following levels: 1.5 percent in sandy soil, 10.0 percent in clay, and 14.0 percent in chernozem.

According to Kostychev's calculations, the amount of usable water on a 2.7 acre area having a depth of one arshin (71.12 centimeters or 28 inches) is as follows: 12,000 pud in sandy soil, 80,000 pud in clay, and 112,000 pud in chernozem.

One way of retaining as much water as possible from precipitation, Kostychev pointed out, is by accumulating snow on fields. He states that the only time soil does not become saturated with moisture is in the spring when snow thaws. Snow lying on fields in winter is not a lifeless cover over unchanging soil. On the contrary, soil moisture, beginning with September steadily increases during the course of the winter and by January is increased by 10 percent to a depth of one arshin.

Criticising the theory held by many scholars that it is impossible to grow trees in steppe regions, Kostychev proved that "the soil of chernozem soils can grow many varieties of plants including both trees and grasses. Trees rarely force out grass, once it begins to grow."

After carefully examining Russian experiments in steppe tree planting, Kostychev confirmed the importance of tree planting in steppes and refuted the idea that forests dry out the soil and for this reason cannot exist in steppes. Kostychev in his work, Pochvy Chernozemnoy Oblasti Rossii, (Soils of the Chernozem Regions of Russia) wrote: "I saw the Velikoanadol'skiy and Bergdanskiy Forests. They were of special interest to me since I found out that a normal summer in these regions had no rainfall until July and had a high, constant temperature. The steppes were literally burned by the sun so that only dry, yellow stems remained. It was remarkable that even during such a summer, trees were fresh and green in all the natural forests (near Kursk and Belgorod), as well as trees planted along railroads; not one tree (excluding those suppressed by weed grass) was harmed, including this year's and last year's planting."

By carefully studying the young trees, Kostychev determined the reason for their high resistance to drought. He dug up the ground around them and found that during dry summers, all life activity of young trees is directed toward growing many deep roots. Roots of oaks (Quercus), ash (Fraxinus), and English elm (Ulmus campestris) grew two meters and were massed in thick tufts which made the ground difficult to plow.

Generalizing from the degree of forest development, Kostychev pointed out that the reason so few forests exist in the steppe area is not because of the climate but because wild grass does not allow forests to expand.

The study of the influence of forests on snow retention in Kostychev's book, O Borbe s Zasukhoy (The Fight against Drought), reveals that in March 1891 there was so much snow in the Velikoanagol'skiy Forest that, had it all melted, the entire area would have been covered by 150.6 millimeters of water. The neighboring open field, however, would have had only 48.2 millimeters of water. By spring of 1892, the forest had 40 millimeters of water in the form of snow, and the open steppe, 20 millimeters. In February 1893, different sections of the forest had accumulated 23-50 millimeters of water in the form of snow. Kostychev stresses the fact that in forest regions the entire water supply is absorbed into the ground. Analyses of soil water content in March 1891 in the forest and in open steppes showed that the forest contained 21.4 percent of water to a depth of one arshin. On the neighboring open field, soil of the same depth contained 17.2 percent water. At first glance, this difference of 4.2 percent may seem to be slight, but actually it is very significant in developing agricultural plants. If one excludes unusable moisture from the total moisture content, 7.4 percent usable water remains in the forest soil and only 3.2 percent in the open field; that is, less than half as much water remains in the open field as in the forest.

After a careful study of chernozem soils, Kostychev established that the entire southwest Dnieper area is composed almost exclusively of former forest land. Large forest areas in the past were also to be found in Penza, Simbirsk, Samara, and Saratov guberniyas; the only traces left of them are a certain change in chernozem composition. Huge forests, which at times occupied large areas of chernozem, greatly influenced the climate and aided in accumulating a considerable amount of moisture. From this, he draws the conclusion that forestry development always serves as an important means of accumulating snow.

Kostychev states that, first of all, trees must be planted in sandy areas, and on slopes of ravines, gorges, and watersheds. Even in this situation, trees will have no influence over a large part of the field area, so that shelter belts in addition to trees must be planted. The shelter belts, which he calls hedges, are located crosswise to the prevailing winds, and in winter can aid in accumulating snow.

Since shelter belts should not be located too close to each other, Kostychev proposed using hedges for storing snow on fields but "only as a base for retaining the first snow. When snowdrifts have been formed alongside the hedges, they will serve in accumulating additional amounts of snow." The end of the snowdrift must be plowed so as to form a snow cylinder which will help store new quantities of snow. Arranged consecutively one after another, the snow cylinders will enable water to permeate the soil more uniformly. Sloping areas having snow cylinders lying across the slope help the water on thawed areas to permeate the soil uniformly and to keep water from flowing into ravines and gullies.

Besides cylinders, Kostychev recommended storing snow by sowing fields with tall, thick stemmed plants such as corn or sunflowers. Stems of these plants are left in the fields during the winter and aid in evenly distributing snow over a field.

Yet, snow retention on fields does not guarantee full protection from drought unless it is followed by a good system of soil cultivation. "When there is a deep layer of snow," wrote Kostychev, "by spring the earth will be well permeated with water. This must be followed by soil cultivation in order to preserve the moisture or there will be little benefit from it, since wet soil dries very quickly." The best method of soil cultivation for accumulating soil moisture, he thought, was fall plowing which facilitates water flowing into the soil during winter and spring.

The following table shows that soil plowed in the fall contains more moisture than unplowed soil:

Table 2

Soil moisture in relation to cultivation

Depth	Soil Moisture (in percent) In soil plowed since fall	Soil Moisture (in percent) In soil not plowed since fall
Up to 2 vershoks	30.0	25.6
From 2 to 6 vershoks	26.3	21.0
" 6 to 8 "	25.8	14.7
" 8 to 12 "	24.6	15.0
" 12 to 16 "	23.3	15.5
Average	26.0	18.4

If, as shown by the above data, 14 percent of the water cannot be used by plants, soil plowed in the fall will contain 12 percent usable water while unplowed soil will contain 4.4 percent. In this connection, the unplowed soil contains moisture only in the upper layers and so is easily evaporated.

What soil condition is best suited for accumulating moisture during the winter? Before answering this question, Kostychev examined several characteristics of chernozem.

During cultivation, chernozem tends to become lumpy. It contains sufficient amounts of humus composed of two gluey substances which are responsible for the lumpy soil. Kostychev carefully distinguished between the two substances. A mixture of clay and sand, for example, with water added can easily form lumps of any size which when dry, become as hard as rocks. If a lump is dampened and then dried, it still remains hard.

Small particles of humus, however, have entirely different qualities. They are "formed only in damp soil and are ten times as sticky as clay. If they form a lump and it dries, it is hard; but upon being wet, the gluey particles disappear and the lump disintegrates." In order to restore the gluey particles, the lumps must be left moist for some time so as to decompose further. Once the particles are restored, they are able to withstand the activity of water and remain gluey until they are again dried.

Lumps of chernozem or of any soil containing a great deal of clay can also be broken up under the eroding activity of water, a fact always important in agriculture. In order to explain the eroding process of water, Kostychev uses examples and comparisons. He notes that if pure porcelain clay is ground up and mixed with water so that no lumps are left, a milky colored mixture will be formed. This mixture forms no sediment and can stand for two years, remaining the same milky color; but if any salt is added to the mixture, the clay immediately forms lumps and settles to the bottom. The same phenomenon occurs when the white of an egg is mixed with water; upon being heated, the egg white forms balls which settle to the bottom. Kostychev points out, that because of this quality, egg whites are sometimes used for purifying water. Egg whites mixed with dirty water are heated, whereupon they form lumps which absorb the dirt particles and settle to the bottom.

"Clay performs the same function in soil as egg whites do in water. The more salt the soil contains, the more compact it is, and the harder the lumps." Rain water, on the contrary, has an entirely different effect on the upper soil layer, since it lacks salts which cause the clay to form lumps. Rain water first washes salts out of the soil and then causes the lumps to dissolve. A solid top layer of soil, a crust, is thus formed. ~~Immediately after a rain, the crust, is thus formed.~~ Immediately after a rain the crust is soft. As soon as the soil begins to dry up and moisture containing salts begin to seep up from lower soil layers, the crust hardens.

From this, Kostychev deduces that "if the crust is harrowed after it dries, hard lumps are formed; while if it is harrowed sooner, it is easily made into a powder. Thus, harrowing must wait until the crust dries to a depth of ½ or one vershok, since the large lumps of soil are much better for preserving moisture and for increasing soil fertility in general."

It was noted above that chernozem has varying structure. Uncultivated chernozem is usually used as pastureland, and has the appearance of a continuous, compact layer, hardly permeable by water. This compact composition of uncultivated chernozem is unfavorable for both accumulating and retaining moisture. Throughout compact chernozem are found capillary pores through which water can pass easily, and be brought to the upper, dryer layer of soil.

Due to these factors, compact chernozem dries out to a considerable depth in dry weather. Loose, powdery chernozem also possesses some unfavorable qualities of compact chernozem, such as inability to accumulate and retain soil moisture. On fields having finely grained soil which quickly forms a top crust, rain water quickly soaks through to lower areas while the plowed soil under the crust remains dry. The crust formed is fairly solid, and moisture coming up from lower soil quickly moves into the more solid upper layer where it evaporates steadily.

Evaporation proceeds more rapidly in lumpy fields. Lumps, being compact, are only slightly permeable so that the water runs between them to the lower, unplowed soil layers. The moisture evaporates first from around the lumps, and then from the lower layers, being carried up by capillary action.

Which soil structure is most favorable for accumulating and retaining moisture? According to Kostychev: "The most favorable is a plowed area composed of small lumps. Water passes easily between the particles, the compact layer is well covered by a cultivated layer so that it hardly dries out, and capillary action in the lumpy layer is made difficult since there is none, or very little capillary water movement between the lumps. With proper care, chernozem can combine the favorable qualities of sandy soil and high fertility with a finely grained layer above the plowed area, which should not be connected to lower layers by a capillary network."

Kostychev considers the cultivation of fallow soil as one of the most effective means of accumulating and retaining moisture. In black fallow, more moisture can be accumulated when plowing is done in the fall. Each additional percent of moisture increases the harvest of grain and straw by nearly 30 pud. Furthermore, fall plowing makes possible more thorough freezing of the soil which also increases the size of the harvests.

Kostychev proved the beneficial effects of frost. He showed that water in the ground does not freeze everywhere at once, but freezes at some places first while other areas remain unfrozen for some time. The areas where ice begins to form attract water from neighboring areas. As a result, pockets of ice are formed and soil between them is drier than it was prior to freezing. The drier ground shrinks in size and dries out, causing cracks to appear. The frozen ground then breaks up into small, compact chunks, favorable for producing a relatively high harvest.

Black fallow should be plowed deeply and should remain for the winter in uneven layers which are able to retain snow on fields. For snowless areas such as the Crimea, where soil moisture evaporates during the winter, Kostychev recommends that harrowing follow the plowing. Harrowing should be done in the early spring when the crust begins to dry, so that another crust is formed which will not draw up soil moisture and at the same time will allow rain to infiltrate the soil. Further cultivation of fallow fields is determined by the weather and by the layer already plowed.

"If heavy rain falls," Kostychev wrote, "and another crust is formed, additional harrowing of the plowed area after the crust is partly dried out is absolutely necessary, even though it is done several days later. But if no rain falls, if the crust remains lumpy and porous, and if between the crust and the lower plowed area no capillary action is formed, no additional work is necessary even though a whole month elapses after the first harrowing."

The job of combatting weeds must be taken care of along with fallow plowing. As soon as weeds come up, they must be destroyed, since they are easier to destroy while young. Each soil contains a huge amount of seeds of weeds which come up and develop during different seasons.

Surface cultivation of fallow fields continues to the middle of the summer. By then, the plowed soil from its own weight and from infiltrating rain water shrinks considerably. In this soil, decomposition proceeds very slowly. A second plowing of fallow is necessary in such cases.

If, following dry weather, it is expedient to plow the soil twice, it is usually unnecessary to make friable the upper layer of soil since it will not have contracted sufficiently. But black fallow cultivated twice in the spring when the top soil layer is not thick is advantageous in a majority of cases.

Prior to fall sowing, soil must be given time to partly decompose. "If soil is very friable," wrote Kostychev, "during sowing, it can easily become powdery and after this form a crust during light rains. On the other hand, if soil partly decomposes before being sowed, it becomes chunky during sowing and the chunks, upon drying, become hard and are not easily disintegrated by rains. The soil can remain in this condition for a long period of time, and is benefited by the easy penetration by air and water, thus providing roots with easy access to air." Well developed plants with an extensive root network extending deep into the soil can utilize the more stable supply of water in the deep soil layers, and, consequently, suffer less from drought.

If for some reason it becomes necessary to postpone fall plowing until the following year, the plowing should be done as early in the year as possible. To confirm this idea, Kostychev cites the following information obtained from Poltava Guberniya concerning the influence of the time of plowing a fallow field on the size of the winter crop harvest: (Table 3)

Table 3

Winter wheat harvest when ordinary fallow is plowed in different periods (in pud)

Year	Plowing fallow in April	Plowing fallow in middle of June
1880	142	63
1883	150	75
1891	201	31

From this, Kostychev deduces that early plowing of ordinary fallow is a very important factor in combatting drought.

In speaking of fallow soil which is usually plowed immediately before the hay harvest, Kostychev points out that as fields dry out, they become considerably more compact, and upon being plowed, are broken up into large lumps. These lumps do not protect the unplowed, solid layer, so that soil moisture steadily evaporates from it.

In this connection, Kostychev pauses on the special significance of the solid layer of soil which is as important for agricultural plants as the plowed layer. No plants utilize only arable soil, since roots extend to lower layers which contain additional moisture and mineral matter. Often these lower, unplowed layers are the only source of moisture and minerals.

In winter, "a large part of the mineral matter passes into the deeper layer, from which roots later obtain it. It is sometimes more important to preserve until fall the moisture in the compact layer than in the plowed layer; the plowed layer lies on top and can be moistened by any fairly heavy rain or by small amounts of snow, while the deep layer is sometimes not moistened even by snow during the winter.

Thus, to waste water contained in the deeper layer would be a mistake." Kostychev was in favor of deep plowing of fallow fields if the plowing were done in the fall or early spring. If done later, deep plowing is useless or even harmful since it exposes the moist soil layer and causes water to evaporate.

As indicated above, a good system of soil cultivation is very important in accumulating and retaining moisture and, thus, in combatting drought. A well cultivated fallow field guarantees high and stable harvests of winter crops and has a favorable influence on harvests of summer crops.

In examining methods of soil cultivation, Kostychev pays special attention to fall plowing. He stresses that the above information in relation to spring or fall plowing of fallow fields also applies to fields growing summer crops, with the difference that fall plowing for summer crops is much more important than fall plowing of fallow. Plowing fields in the spring, rather than the fall, causes soil moisture to be wasted, and so delays spring sowing. The delay aids the growth of weeds, which quickly choke out the young plants.

Soil cultivation in steppe areas long ago established that freshly plowed virgin soil is very fertile and guarantees high harvests. Kostychev explains this scientifically. In 1881, the magazine Sel'skoye Khozyaystvo i Lesovodstvo (Agriculture and Forestry) printed his work "Iz Lesnoy Polosy Voronezhskoy i Khar'kovskoy Guberniy" (Information on forest regions in Voronezh and Kharkhov Guberniys) in which he stated that fertility is determined by the physical composition of the soil. In another article, "K voprosy ob obrabotke i udobreniye chernozemnykh pochv," (1888), Kostychev wrote: "After plowing, the upper layer of virgin soil is transformed into small pieces the size of peas. Under these conditions, harvests, even during dry years, produce first-class quality, hard wheat." In steppe areas where there were large areas of unplowed soil, one area was sowed for 5-6 years, primarily with summer crops, after which the land remained unplanted and a new section of virgin soil was plowed.

As the population in the chernozem regions increased, unplanted areas were cultivated before they began growing couch grass. Often couch grass areas were used for pastures. Kostychev deduced, that the only way to prevent this weed from growing was to plant grass on the fields.

It was difficult to solve these problems of soil cultivation while a small peasant economy existed. Realizing this, Kostychev wrote: "Unfortunately, grass sowing in chernozem areas is still the most backward part of the economy." Several scholars explained the first unfortunate attempts at grass sowing as being due to the climatic conditions of the chernozem area, where perennial grasses cannot be grown. Kostychev showed the fallacy of similar statements and then disclosed the true reasons for unsuccessful field sowing. In his conclusion to <u>Bor'ba s Zasukhami</u>, he wrote: "We suffered many losses because we plowed our fields by the Western European methods which are not suited to our climate."

In this connection, Kostychev wrote that in dry chernozem steppes, either grain or grass can be grown, but both cannot be grown at the same time successfully. Only during a rainy summer is it possible to have well developed perennial grasses growing with cover crops.

For growing crops of grain for fodder, the ground must be plowed one more time after the fall plowing. Prior to the main (first) fall plowing, the soil must be in a condition which will enable all weeds to be destroyed by the final deep plowing. Grass for fodder must be sown in the early spring. In addition to this, Kostychev recommended that perennial grass varieties which are adapted to the soil and climatic conditions of an area be sown.

These ideas of Kostychev -- the development of soil cultivation in chernozem steppes, the restoration of a durable, finely grained soil, its ability to accumulate organic matter, and the processing of soils by the most modern methods of soil cultivation to prevent drought — are a very important addition to the development of a scientific basis for soil cultivation. His work on soil fertility and methods of restoring soil fertility have been used as an integral part of the grass field system of soil cultivation.

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