CONSERVATIONAL SOIL TREATMENT

Volodin V.M., Cherkasov G.N., Rozhkov A.G., and **Pykhtin I.G.**
All-Russian Research Institute of Agronomy and Soil Erosion Control, Kursk, Russia

Keywords: erosion, deflation, conservational soil treatment, inclination, eroded lands, anti-erosion organization of territory, contour lines, guidelines, buffer strips, degraded soils, inclined cropland, terracing, forestation, vegetative cover, erosion-prone period, anti-erosion resistance, anti-erosion complex, adaptive-landscape approach, linear border, degree of steepness, tolerable level, rational placing of crops, soil-protecting, capability, conservational soil processing, no-till, plant residues, stubble, seeded haylands, water-preserving forest belt, wind-breaking belt, strip agriculture, water-retention effect, mulching, stubble breaker, plant residues, crevice-cutter, socket making, mole-hilling machine, siltation, surface runoff regulation, artificial soil conditioning, artificial structure-formers, polymer preparation, irrigation erosion, furrow irrigation, check irrigation, spray irrigation, drop irrigation, sprinkling

Contents

Summary

This article considers practical measures to protect soil from erosion and deflation. It has been noted that in regions where water occurs, great attention should be paid to the anti-erosion organization of the areas that form the framework of the following linear borders: forest belts on cropland, road networks, the borders of agricultural lands, crop rotations and fields, ridge-terraces with wide bases, and others on slopes.

Water-preserving forest belts should be located on straight, even slopes across their inclination, and along the contour lines on complex slopes. Forest belts perform a range of functions over long periods, and the ground leading to them should be solid, as roads and field tracks are generally associated with them. They serve as guidelines for the

movement of agricultural machines when soil is being processed, crops are being sown and cared for, and anti-erosion practices are being applied on slopes.

In regions where there is deflation, wind-breaking forest belts are laid out across the main deflation-prone areas. Strip sowing, buffer strips of grasses, and other measures to protect soil from wind erosion are placed along them.

The basic methods of soil processing (tillage) and soil management practices applied in conservational soil treatment are described in detail. The article considers the effects of crevice cutting, socket making, mole-hilling, and also of moldboardless, chisel, surface, trash-cutting, and other kinds of tillage on wind and water erosion, on moisture retention, conservation, and crop yield. Technological schemes of meadow making on eroded lands and their impact on soil and environment protection are outlined.

1. Introduction

The term "conservational soil treatment," along with the conventional definition of farming systems, can be applied in a wide sense to the protection of soil from all kinds of degradation in order to conserve its fertility, make efficient use of land resources, increase the yield of cultivated crops, and diminish negative ecological effects. The term is often used in a narrower sense for measures to protect soil against erosion and deflation processes. Erosion and deflation affect 84% of the total area of degraded soils.

The destructive effects of water running down sloping cropland have apparent to farmers throughout history in the years after new parcels of land has been reclaimed by plowing up natural vegetation or cutting down the forest and clearing the land. To prevent soil loss and scouring on the reclaimed slopes and to protect crops from perishing, farmers have sought the best protection they could in the light of the knowledge available to them.

Terracing, afforestation of mountain slopes, and soil processing across the slope are among the most ancient practices of protecting soil from destruction by erosion and deflation. Terracing steep mountain slopes to grow valuable fruit crops and forests on them was practiced in ancient China, by the Incas in the territory of present-day Peru, in Armenia, in many Mediterranean countries, and in a number of other regions. Terraces were built by hand, sometimes with sheer slopes made of masonry. This reduced soil loss considerably but could not completely protect the land from erosion, especially when there was heavy rainfall with a considerable precipitation layer. Terraces were frequently damaged, and had to be rebuilt, but even so many ancient terraces have lasted in good condition in a number of countries until the present time.

One of the most ancient and simplest ways to protect soil from erosion is soil tillage and placement of plant rows across the slope, a method used in ancient Rome. At present soil tillage across the slope or along the contour of the horizontal lines of the locality under cultivation is considered to be one of the fundamental elements of conservational soil treatment. An interesting detail is to be noted: almost two millennia passed between the first recorded use of tillage across the slope and the first application of contour tillage.

At present, however, these elementary anti-erosion practices are performed only on part of the total cropland area even in highly developed countries.

For many centuries the negative effects of erosion actually went unnoticed by scientists and statesmen. Only in a number of European countries (Austria-Hungary, France, Germany and some others) were official policies adopted at government level to prohibit plowing of mountain slopes and encourage afforestation of steep slopes and lands ruined by gullies. In general, there was neither investigation of surface water and wind erosion nor any developing and experimental testing of conservation practices on plowland.

It was only in the first quarter of the twentieth century that special experimental stations for the study of causes and mechanisms of erosion and deflation processes, and the mapping of eroded and deflated soils and their extension, were founded in the United States and a number of European countries. For the first time conservation farming practices started to be developed, and their effect on water runoff, water and wind erosion, and their impact on major crop yields experimentally were evaluated (see *Soil Conservation*).

Information accumulated by researchers made it possible to objectively reveal the scope and harmfulness of erosion and deflation for agricultural production and the environment. The need to adopt conservation soil treatment was put on a firm scientific basis.

Currently a large number of anti-erosion (conservation) agrotechnical, chemical, meadow-and-forest meliorative measures and hydrotechnical constructions have been developed by world science and practice to prevent and reduce soil loss from erosion and deflation. In different natural zones, and under differing local conditions inside single zones, a varying number of different measures and practices may be used. The selection of particular methods depends on the specific genetic features of the soil concerned, its actual erodibility, the degree of dissection of relief by ancient and contemporary forms of scouring, peculiarities of how precipitation may lead to surface water runoff, the soil-protecting properties of crops, the intensity of erosion processes, and a number of other factors. But the efficiency of anti-erosion practices—or their combination (complexes)—will depend significantly on their proper location in the relief, that is, on the anti-erosion organization of the territory of a particular farm, river basin, or catchment of a ravine.

That is why anti-erosion organization of territory—laying out the borders of fields, crop rotations, and crops so as to reduce soil loss from erosion and increase productivity—must be performed in all zones where soil erosion is present and measures to protect soil from destruction by erosion processes are planned to be used.

2. Anti-Erosion Organization of Territory

Anti-erosion organization of territory forms an organizational-economic unit of the whole complex of conservation farming methods, and is the foundation that creates conditions for an efficient managing system of producing and protecting natural resources (see *Soil-and-Water-Protecting Soil Treatment*). The territory organization (arrangement of agricultural lands) can be carried out by an agricultural enterprise or a private land user (landowner), either to an existing available model design that is suitable for the natural and economical conditions of the farm, or to a design can be ordered from a specialized design organization or service. Such arrangements are designed according to the requirements of national or local nature-protecting programs. The range of problems to be solved includes the following:

- The natural and economic resources for agricultural production need to be analyzed, along with the degree of their influence on specialization and technology of production. The forms and intensity of erosion processes must be estimated, taking into account the relief conditions, mechanical soil composition, precipitation and wind regimes, projective vegetative soil cover in erosion-prone and deflation-prone periods, the scale and effect of anthropogenic impacts on the anti-erosion resistance of soils, and the overall functioning of the agrolandscape.
- Land areas must be classified by their intended use, warmth and moisture resources, duration of vegetation period, level of soil fertility, uniformity of meliorative impacts, and the intensity of predicted soil erosion in their planned use.
- The damage likely to be caused to production and environment erosion processes must be evaluated. The kinds and amounts of anti-erosion measures for each typological land allotment must be estimated, taking into account their role in the technological process of crop growing and the soil-protecting properties of crops themselves.
- The planned crops must be selected on the basis of the resources of the local landscape and its capacity to provide their physiological needs (which may be artificially supplemented by material and mechanical means).
- In the distribution of crop rotation fields, working plots must be created in areas with soils of similar quality. The size and the shape of these uniformed areas should be taken into consideration, as should the specific use of agricultural machinery. Pasture and hayland rotation plots, recreation and micro-reserve areas should be distributed on lands suitable for them.
- Linear borders must be laid out and coordinated, in the form of road networks and other communication lines, field borders, windbreaks, runoff controls, and other elements of the anti-erosion complex such as natural ephemeral streams, water-discharge and water-retention constructions.
- The plan for the projected measures must lay down the sequence in which individual elements of the anti-erosion complex will be introduced, and take account of landscape formations that are resistant to external uncontrolled impacts.

The solution of these problems must be based on the adaptive-landscape approach to nature use, and on observation of a number of definite principles:

- Specialized production and cropping systems must conform to the natural conditions of the locality, bearing in mind its vulnerability to soil erosion and deflation.
- As little valuable land as possible should be used for anti-erosion constructions and measures.
- Soil protection should be provided if it is necessary by changing the structure of land use and introducing new crops.
- The resources and environment on every field and working plot should be made sustainable.
- Technological tillage methods should be combined with field management measures to protect soil from erosion and deflation.
- Machines and implements in a cropping system should be used in ways that do not exceed the agroecological limitations to technogenic loading on lands;
- The properties of crops should be used to the maximum to dissipate the energy of water and wind streams by means of complete and thick projective vegetative cover of soils in erosion-prone periods and to improve the anti-erosion resistance of soils.

The essence of the anti-erosion organization of territory is:

- Placement of linear borders across slopes and along contours. These borders may be forest belts, inner farm roads, or the borders of agricultural lands, crop rotations, and fields, which divide long slopes into shorter sections.
- Differentiated placement of crop rotations and use of technologies of crop growing that take account of soil fertility, the soil's vulnerability to erosion, and microclimatic conditions on slope elements.
- The use of the necessary field management and agrochemical measures between the linear borders on more erosion-prone slopes, and of hydrotechnic constructions in the form of mountainous terraces with a wide base. These measures make it possible to reduce soil loss and scouring to tolerable levels, to raise crop yield, and to lower the ecological effects of erosion considerably (see *Soil Management for Sustainability; Biotechnical and Soil Bioengineering Slope Stabilization*).

Work on the anti-erosion organization of territory is performed by specialized project organizations working to the specifications of an agricultural enterprise or a farmer. Soil-erosion maps on a scale of up to 1:10 000 are drawn up to show the basic watershed lines limiting the catchment area where the surface runoff of shower and/or snowmelt waters, soil wash, and scouring take place. On every watershed, slope sections of different steepness are singled out so that the intensity of erosion processes can be analyzed. Slope steepness can be determined in gradients, tangents of the inclination angle, or as a percentage (Table 1).

Slope	Steepness grade	Inclination	
		tangent	percent
Very flat	1	0.017	1.7
Flat	1-2	0.017-0.035	1.7-3.5
Slanting	2-5	0.035-0.087	3.5-8.7
Slanting-steep	5-9	0.087-0.158	8.7-15.8
Steep	9-20	0.158-0.364	15.8-36.4
Very steep	20-30	0.364-0.577	36.4-57.7
Extremely steep	30-45	0.577-1.000	57.7-100.0

Table 1. Classification of slopes by the degree of steepness

On the cropland of the forest-steppe and steppe zones with gray forest and chernozem soils, slopes can be classified according to steepness: those with gradients up to 3, those between 3 and 5, and those above 5. These gradients are related to erosion processes, and grouping slopes by the degree of steepness adequately reflects the distribution of soils by fertility. On slopes up to a gradient of 3, full-profiled uneroded or slightly eroded soils predominate; on slopes of 3–5 grades there are slightly or middle-eroded soils; on slopes steeper than 5, moderately and severely eroded soils predominate.

In other climatic zones, and especially in mountainous and pre-mountainous areas, slope grouping by the degree of steepness and soil fertility can differ considerably from the one given above. However, in all cases classification must be based on the ratio of the intensity of erosion processes to the process of natural soil formation.

Borders of slopes that are different in their degree of steepness and soil erosion serve as borders for differentiated placement of crop rotations.

Flat areas of watershed plateaus, and slopes with gradients of less than 3, which tend to have the most fertile soils and be slightly eroded, are allotted to the intensive type of crop rotation, in which row crops and fallow occupy up to 50–60% of the area. Slopes with gradients between 3 and 5 and mildly or moderately eroded soils, are generally used for grain–grass crop rotation with predominating grain cereals and annual grasses. Slopes with gradients of 5 or more, the least fertile soils, and intensively expressed erosion processes, require a grass and grain soil-protecting crop rotation in which up to 40–60% of the area is occupied by perennial grasses.

The following requirements apply to the placement of the borders of crop rotations, fields, and working plots in conditions of complex relief:

- Individual crop rotations and crop rotation fields are placed on lands that are similar in their soil and relief conditions and uniform in the intensity of erosion processes.

- The long side of the borders of the rotation fields of working plots is placed across the slope or along the contour, similarly to the location of water-preserving forest belts, buffer strips of grasses and shrubs, field roads, and other linear borders, in order to serve as a guideline for soil tillage and crop planting.
- The end borders of fields must align with gully tops or extend into plowed dingles and hollows.
- Where suitable borders to homogenous areas cannot be established, because of slope steepness and the degree of soil erosion, small areas of less eroded lands are joined with the plots of more eroded lands, and less steep plots with steeper ones; and
- On even, regular slopes, the parallel horizontal borders of crop rotations, fields, and all other linear borders are placed strictly across the slope, in other words along horizontal lines.

On prominent and concave forms of slope where their orientation relative to the cardinal points is different, it is often impossible to arrange borders and the like along the contours. Placement of linear borders along the horizontal lines in such cases would produce plots of different width and shape, and some parts of the area would be separated from the cropland. This would make soil tilling and crop cultivating, and the use of agricultural machinery, much more difficult. The technique of placing linear and other borders strictly along the horizontal lines is usually recommended for slopes with intensive soil loss and soil scouring.

For less erosion-prone lands on slopes, especially on the upper parts of the catchment contiguous to the flat watershed area, linear borders may be allowed to deviate from horizontal lines. To prevent soil loss and soil scouring, the length of linear borders and their secondary inclination must not be such as to allow water streams to reach above tolerable erosive velocities for individual soils and subsoils.

It is more difficult to perform the proper organization of territory in regions with complex relief and combined water erosion and deflation, since the direction of the winds that cause deflation is frequently different from the direction of streams of running water formed during snowmelt and shower rainfall. That contradiction is usually solved in the following way. On flat areas and contiguous slopes with gradients of up to 1 or 2, long field borders and wind-breaking forest belts are located across the direction of the winds. Within the fields, if necessary, additional measures are aligned in the same direction. These include buffer strips of high-stemmed grasses, strip planting of crops, and flat tillage with stubble being left on the surface.

When such conditions apply on more steeply sloping land, the requirements for the anti-erosion organization of territory and placement of linear borders remain the same as in regions where only water erosion occurs.

The final stage of anti-erosion organization of territory is planning for individual plots, rotation fields and the whole watershed, and implementing practical methods and practices and their combinations (complexes) to retain the expected water runoff, reduce soil loss to a tolerable level, prevent the formation of gullies, and prevent fertilizers and pesticides from slope lands from entering water reservoirs.

It is economically viable to design a complex of anti-erosion measures to retain snowmelt and rainwater runoff where there is a 10% probability, that is, a frequency of once in ten years. In areas where the frequency is less, anti-erosion organization will entail planning for emergency discharge of excess uncontrolled water runoff. On slopes under cropland such constructions usually take the form of unplowed depressions with natural grass cover, or artificial grassed waterways and steep concrete channels.

-
-
-

Bibliography

Agassi M. (ed.). (1995). *Soil Erosion, Conservation and Rehabilitation.* Marcel Dekker. [This presents contemporary knowledge in the field of surface runoff formation and water erosion on agricultural lands, methods of their prevention and control.]

Gray D.H., Sotir R.B., and Grey D.H. (1996). *Biotechnical and Soil Bioengineering Slope Stabilization: A Practical Guide for Erosion Control*. John Wiley. [This presents methods of protecting slopes from erosion by applying different species of vegetation (including grass cover) and terracing.]

Hudson N.W. (1971). *Soil Conservation*, 320 pp. London: Batsford. [This presents the results of soil erosion research in the torrid belt and measures on soil conservation.]

Kashtanov A.N. and Zaslavskiy M.N. (1984). *Soil- and Water-Protecting Soil Treatment*, 462 pp. [In Russian.] Moscow. [This presents causes, conditions and effects of soil erosion and deflation. Major practices of soil-protecting farming are described in detail and their economical and ecological efficiency is given.]

Lal R. and Pierce F.J. (eds.) (1991) *Soil Management for Sustainability*, 189 pp. Iowa. [This presents the results of investigations into different kinds of soil degradation and management of degradation processes.]

Biographical Sketches

Victor Mitrofanovich Volodin was born in 1939 in Russkaya Zhuravka, Verkhne-Mamon district, Voronezh province, Russia. After finishing secondary school in 1956 he worked on a collective farm, then entered the Voronezh State University, graduating in 1965 and then working as a specialist in soil science and agrochemistry. In 1971 he became a postgraduate at the Tselinograd Agricultural Institute, and in 1971 obtained a candidate’s degree in biological sciences. Then he worked as senior teacher and assistant professor.

From 1974 till 2000 V.M. Volodin worked at the All-Russian Research Institute of Agronomy and Soil Erosion Control as senior scientist, head of laboratory, head of department, deputy director, and director. In 1991 he obtained a Doctorate in Agricultural Soil Science. In 1995 he was elected a corresponding member of the Russian Academy of Agricultural Sciences.

He was engaged in research work for 30 years and was one of the leading scientists in the field of agricultural soil science and agronomy, publishing 130 papers including five monographs. He founded a new scientific school of agricultural bioenergetics, formulated a concept for the estimation of soil fertility and crop farming systems on the bioenergetic basis, revealed the regularities of the process of the extended soil fertility reproduction and the sustainability and stability of crop farming, and suggested new approaches to crop-farming classification based on ecosystem theory. He was one of the authors of the fundamental tenets of the concept of forming ecologically balanced agricultural landscapes. He was a winner of the State Prize of the Russian Federation for developing the theory and methods of managing ecologically balanced agricultural landscapes. He successfully combined his scientific and research work with pedagogical activity, lecturing on ecology for students and undertaking guidance of post-graduate students.

V.M.Volodin died on December 26 2000.

Grigoriy Nikolayevich Cherkasov was born in 1948 in the village of Konetzpolye in the Baryatinsk district of Kaluga province, Russia. After finishing secondary school in 1965 he entered the K.A. Timiryazev Agricultural Academy, Moscow. He graduated in Agronomy in 1971 and entered a postgraduate course at the same academy, gaining his candidate's degree in 1976. He has been occupied in scientific and research work for 25 years, 23 of them in the All-Russian Research Institute of Agronomy and Soil Erosion Control, Kursk. He has served as junior and senior scientist, head of laboratory, deputy director, and director, and published more than 90 papers including four monographs.

The principal areas of his research work concern: methods and technologies of improvement and productivity increase of natural fodder lands on erosion-prone and eroded slope lands; technologies of reclamation of gully-ruined lands for hay- and pasturelands; regularities of erosion processes on slopes and measures of soil protection from erosion; scientific principles of forming ecologically balanced agricultural landscapes and soil-protecting farming systems. He obtained a Doctorate in Agricultural Sciences (with a speciality of Common Agronomy) in 1996 with a thesis on scientific principles of rational land use and raising the productivity of natural fodder lands in the gully and ravine system of the forest steppe of the Central Chernozem Zone.

G.N. Cherkasov is a winner of the State Prize of the Russian Federation for developing the theory and methods of managing ecologically balanced agricultural landscapes.

Alexander Georgiyevich Rozhkov was born in 1926 in the village of Shatalovo in the Oryol district of Oryol province, Russia. In 1950 he entered the Voronezh Institute of Forest Engineering. In 1955 he graduated in Agricultural Forest Melioration, and entered a postgraduate course at the Moldavian Dimo Research Institute of Soil Science and Agrochemistry. He obtained a candidate's degree in 1963 with the research "Investigation of the process of plowing terracing of slopes." In 1972 he obtained a Doctorate of Agricultural Sciences (Common Agronomy) with the research topic "Gullies, their melioration and agricultural use."

He has been engaged in scientific and research work for more than 40 years. For about 30 years he has been working at the All-Russian Research Institute of Agronomy and Soil Erosion Control, Kursk, 11 of them as deputy director. He has published more than 200 papers, including nine monographs and booklets. The main directions of his research work are: regularities of soil loss and gully formation; effects of natural (precipitation, soil, relief, etc.) and anthropogenic factors on the intensity of erosion processes; development of technologies of slope terracing with different machines; development of technologies of gully leveling and melioration of gully-ruined lands; study and estimation of the soil-protection and nature conservational efficiency of different anti-erosion measures (slope terracing, forest-meliorative and agronomical methods, hydrotechnical constructions for gully reinforcing, ecological consequences of soil erosion and others).

Ivan Grigoryevich Pykhtin was born in 1937 in Kommunar, Beloye district, Kursk province, Russia. He entered the Rylsk Agricultural College in 1951. In 1955 he graduated in the speciality arable farming and entered the Voronezh Agricultural Institute, from which he graduated in 1960 in the speciality agronomy.
From 1960 to 1963 he worked as an agronomist in a sugar-beet-growing collective farm. From 1963 to 1975 he worked on the Lgov Experimental Selection Station as junior and then senior scientist, and manager of the experimental field. There he defended his thesis for a candidate's degree in agrochemistry.

He conducted two long-term field experiments on the influence of long-term fertilizer application on soil fertility and productivity of crops.

Since 1975 he has been working at the All-Russian Institute of Agronomy and Soil Erosion Control, Kursk, as senior scientist and head of laboratory. He has been conducting a number of long-term multi-factor field experiments on the influence of fertilizers, pesticides, methods of soil processing, crop rotations, and other factors on soil fertility, productivity of crops, and development of erosion processes.

In 1994 he obtained a Doctorate in Common Agronomy, with the research topic “Agroecological principles of crop rotation productivity in the forest steppe of Russia and Ukraine.” His scientific interests are agrochemistry, crop farming, and ecology.

He is the author of 80 papers, about a third of which are of a theoretical and methodological character. He established the principles of constructing and managing crop farming systems, crop rotation, and systems of full soil processing, and determined more exactly the main effects and the character of the interaction of individual natural and anthropogenic factors.