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Soil-water-security Systems of Agriculture and Adaptation to Changes of Climate

Svetlana Vasilievna Budnik*

The central geophysical observatory of a name of Boris Sreznevskogo, Kiev, Ukraine

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ABSTRACT

In article the expediency of application of methods of protection soils from erosion and in general principles of the antierosion organization of territory of land tenure for adaptation of territories to changes of a climate is considered. The expediency of updating of these methods in connection with new results of supervision for runoff on slopes and the new purposes of their application is shown. In particular, it is shown, that antierosion constructions need to be placed above a place of concentration of a runoff, instead of on it as the probability of destruction of a construction in this place is great. Application the soil-water-security systems of agriculture provides regulation of a microclimate of territory (reduction of warming up of a surface), allows to lower peak of a high water from downpours, translating a part of a superficial runoff in intrasoil and underground and to these to prevent losses from them including loss of a fertile layer of soils, saturation by a moisture of a zone of aeration favorably influences development of forest vegetation and agricultural crops.

1. Introduction

Changes of climate of last years mentioned practically all corners of globe, polar ices thaw, desertification of steppe territories, etc. are observed^[4,12,16,18,26]. In documents WMO, FAO etc. appeals to necessity of adaptation of territories to changing conditions of environment for maintenance, both food safety of the population, and personal and their material security from spontaneous displays of a changing climate^[4-6,17,38,39].

Among spontaneous displays of change of a climate name non-uniform redistribution of atmospheric precipitation in a year and increase in extremeness of their loss

^[14,26,29,37], i.e. precipitation become more intensive, and their loss leads to formation of short-term floodings of extensive territories and is frequent to a loss of property, and sometimes and to human victims. Non-uniformity of loss of precipitation in time also results, frequently, in a loss of property as can lead to loss of a crop, the aggravation of phytosanitary conditions in region, etc. For steady functioning geosystems needs regulation of distribution of heat and a moisture on territory, creation of a favorable microclimate of adjacent territories will promote stability of all geosystem as a whole. The mechanism, capable adjust spontaneous displays of changes of a climate the organization of territory of land tenure (agro-, forest-,

*Corresponding Author:

Svetlana Vasilievna Budnik,

The central geophysical observatory of a name of Boris Sreznevskogo, Kiev, Ukraine;

Email: svetlana_budnik@ukr.net

hydro-land improvements, rational and coordinated with a lay of land, accommodation of roads, fields, and other boundaries), widespread on all territory of a catchments basin of a problem zone can to act. About effective use of the organization of territory of land tenure in prevention of erosive processes and regulation of a water mode of territory not few works ^[9,12,27,29,28,30,31] are already written and works according to similar recommendations were conducted on separate parts of problem territories. Even are available more than the centenary experiences incorporated still V.Dokuchaevym in Stone steppe and on stream (arroyo) catchment of the river Derkul (inflow of the river Severski Donets) with application of water-retaining dams on the hollows running into a beam, with landings large forests and forests strips which exist and to this day, creating a special microclimate in initially steppe territory which have been strongly cut up by ravines, and keeping natural kinds of plants and animals, that already seldom meet on the steppe files located by a number at practically full turfs before existing ravines. However, for full scope of problem zones yet does not suffice either means, or aspirations. Changes of climate, anyhow, nevertheless compel to search for decisions, and these decisions are in complex use of the saved up experience.

Stabilizing influence on geosystem render, as actions on protection of ground against erosion (regulation of carry of heat and energy in geosystem), and optimization of territory of land tenure concerning preservation of a necessary level of humidifying of soils, maintenance of satisfactory fytosanitary conditions, etc., actions on a layout of the occupied places for prevention of floodings and formation of streams of the water destroying an infrastructure of settlement, etc. of Action of constant action (shaft-ditches, roads, forests strips, etc.) interrupt concentration of a superficial runoff and promote translation of a superficial runoff in intrasoil than slow down promotion of water to places of unloading - to the rivers, lakes and the seas. It promotes decrease in peaks of high waters, them flattening in time and provide a soil feed of the rivers that is important for functioning water ecosystems in low-water. Importantly there is a selection of specific parameters of the actions entering into the organization of territory, capable to provide necessary stability.

2. Methods and Materials of Researches

The analysis of references, materials of long-term supervision over formation of a runoff from slopes from downpours was spent and at snowmelts ^[8-11] with the purpose of an opportunity of application of existing technologies of the organization of territory of land tenure, including antierosion, to adaptation of territories to change

of a climate, and also their some updating on the basis of natural supervision.

3. Results of Researches

Among the basic antierosion actions now allocate hydraulic engineering (shaft, shaft-ditches, terraces, etc.) and agrotechnical (agricultural background, their alternation on a slope, processing of slope). For construction of hydraulic engineering, water-carrying and other constructions on slopes calculation of the basic hydrological characteristics of time water-currents (a runoff, washout and the maximal depth of water) on slopes, mostly, on the basis of the long-term provided climatic sizes of sediments, temperatures, etc. Depending on speeds of running off or volume of a runoff is spent and (or) depending on volume of washed off soils from slopes places where the stream reaches their critical sizes are defined, and distances between flow regulation boundaries are appointed. Last way is considered the most proved since allows to estimate at once results of soil-protective system of agriculture and efficiency of various actions.

Distinctions in techniques applied now lays not only in various approximating methods of calculation, but also in distinctions of applied schemes of formation of a runoff and loss.

Schemes of formation of a runoff of water on slopes can be classified on distribution of a layer of water on length of a slope; on character of running off of water on a slope.

On distribution of a layer of water on length of a slope

R.E.Horton's scheme ^[22]: depth of water accrues on length of a slope. Dependence has sedate an appearance: $h=aL^b$;

A.N.Befani's scheme ^[2]: depth slope streams depends on a difference between time runoff formation and time sloping lag-time) if time runoff formation exceeds time sloping lag-time depth slope streams essentially increases from a watershed downhill; in this case it is considered, that formation of a runoff on all slope occurs as a full runoff; if time runoff formation is less than lag-time - depth on length of a slope does not change (incomplete type runoff formation).

B) On character of a longitudinal structure of a slope

1) the runoff goes a continuous veil on all surface of a slope (a plane runoff) ^[34];

2) the runoff occurs mainly in streamlets ^[2];

3) rill and interrill a runoff ^[19].

Schemes of formation of washout of a slope are subdivided under the factors, A) factors providing loss; B) on character of a longitudinal structure of a slope; C) on

scope of the water-modular area.

A) Under the factors providing loss

1) loss arises, if speed of a stream reaches washing away speed^[3,32];

2) loss arises, if tangents of a pressure reach critical sizes^[19];

3) the zone of increase of intensity of loss of soil on length of a slope is limited by length of a way lag-time "separate section" (divides "a full runoff" from "an incomplete runoff" on long slopes)^[33,36];

4) fall a slope (carrying out products denudation) occurs up to a place where the stream passes in the stated condition, below on a slope adjournment of sediments^[1] (on transporting ability) is observed;

5) the combination of mechanical and chemical factors of destruction of a surface of a slope, is closer to a watershed a role of chemical factors is more significant mechanical^[9-11].

B) On character of a longitudinal structure of a slope

1) the slope on length shares on three zones: a belt of absence of erosion, a zone of active erosion and a zone of adjournment of sediments^[23,28];

2) a slope on length can be divided, at least, on 4 zones, 2 from which periodically repeat downhill. The first zone is length of concentration of a runoff here loss is not formed. The second zone - initial length of loss - here depth of loss increases downhill. The third zone is a length of sedimentation of sediments. The fourth zone is length of critical loss. Here there is a catastrophic loss on rather small site of a slope (0,2-1м - depending on character of a water-current and length of a slope). Behind the fourth zone there is an alternation of a zone of sedimentation and a zone of loss^[8-11].

C) On scope of the water-modular area

1) having washed away mainly in channels of streams;

2) loss of all surface of a slope;

3) rill and interrill erosion^[19].

Methods of calculation of a runoff on slopes can be subdivided in the next way

1) use of various updating of system of equations Saint-Venants^[3];

2) empirical dependences^[7,20].

Practically in all schemes and methods some assumptions and simplifications of representations about formation of a runoff and washout are accepted. Schemes of formation of a runoff and washout differ, notwithstanding what these processes are connected among themselves. Distinctions in features of the arising practical problems connected with склоновыми by processes, compel to resort to various methods of the decision doing accent either on a runoff or on washout.

Frequently in a choice light exposure of the information and development of a question is solving. Most a weak spot is absence of a natural material of researches.

Absence of the regular long-term given supervision over formation of a runoff on slopes was the reason of more thorough study of mathematical models склонового a runoff on the basis of the equations of hydrodynamics^[2,21,24,15,34,35].

Calculations on our materials of supervision for sloping a runoff also show, that communication between the charge of water and its depth rather close, and for downpours factor of correlation of communication above, than for snowmelt while the relative mistake is less for a thawed runoff, nevertheless, it is possible to approve, that communication exists.

Distances between constructions can be appointed proceeding from a condition of achievement a stream of washing away speeds or critical volumes of water, critical silt charge waters, etc. That is the construction is projected in a place of concentration of a runoff where concentration of all power forces of a stream and probability of destruction of a construction is observed is maximal.

Proceeding from supervision over formation a runoff on slopes (as already it is told above by consideration of schemes of formation of washout of a slope on character of a longitudinal structure of a slope a slope on length it was possible to break into some zones it is 1) the zone of concentration of a runoff (Lv), here loss is not observed, 2) the zone of the beginning of loss (Lo), here is observed gradual increase in depth gullies on length of a slope, 3) the zone of adjournment of sediments, here is observed reduction of depth of loss downhill up to its full absence and adjournment of sediments (Lot), 4) the zone of critical loss, here occurs catastrophic loss of soils (Lкр) (Figure 1). Behind a zone of critical loss there is an alternation of zones of adjournment of sediments and zones of critical loss (Figure 2). Borders of zones are dynamical and depend on conditions of formation of a runoff. Frequency and amplitude of fluctuations of depth of loss change year by year and from a downpour to a downpour depending on conditions of formation of a runoff and character of a spreading surface. In a zone of the beginning of loss primary influence on loss is rendered with a chemical component of destroying force of a stream of water, in a zone of adjournment of sediments - dynamic. For a zone of critical loss we can ascertain significant change as silt charge waters, pH waters, and change of the maintenance practically all elements in water. In this zone both chemical and dynamic components are equally significant.

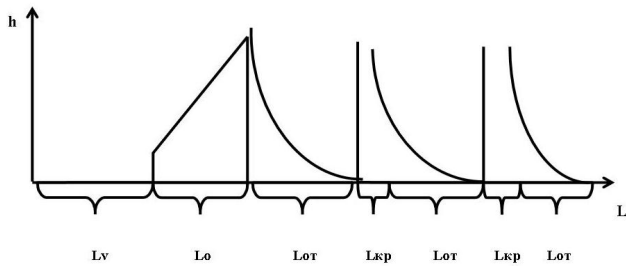


Figure 1. Scheme of washout of a slope a water-current on length.

(h - depth of loss, L - length of a slope from a watershed)



Figure 2. Alternation of places of loss in the bottom part of a slope on rangelands a slope

Proceeding from all above told it is necessary to expect, that on the short sites of a slope created at construction of hydraulic engineering constructions on slopes the greatest influence on washout the chemical component of destroying force of a stream will render.

As it has been told above, in existing recommendations of distance between stream flow control boundaries are defined depending on speeds of running off or volume of a runoff or depending on volume of washed off ground from slopes. Calculations are conducted or by definition of distance at which having loss of soils exceeds admissible, or by comparison of volume of a runoff with volume of water which the planned construction is capable to detain. However, it is possible to use and such parameter as

depth of loss. So, according to the requirements put forward earlier the first construction from a watershed should be located above a place of the beginning of concentration of a runoff where loss is not present. For the decision of the given problem it is necessary to break, first of all, a slope on corresponding zones and to lead calculation of their borders.

Proceeding from all above told it is necessary to expect, that on the short sites of a slope created at construction of hydraulic engineering constructions on slopes the greatest influence on loss of the chemical component of destroying force of a stream will render.

For forecasting places for a slope where loss of soils is most probable, it is expedient to take advantage of methods of optimization (mathematical programming). As criterion function it is possible to accept the longitudinal area of loss of a slope consisting of pieces above the listed zones. By its optimization on a maximum places on a slope where intensive loss of soils will be observed are defined. By its optimization on a minimum places on a slope where loss will not be are defined. Then the longitudinal area of loss (W) will be defined by criterion function:

$$W = C_1L_v + C_2L_o + C_3L_{ot} + n(C_4L_{kp} + C_5L_{ot}) \rightarrow \min (\max).$$

The system of restrictions includes the following equations:

Restriction on length of a slope:

$$L_v + L_o + L_{ot} + n(L_{kp} + L_{ot}) = L_s.$$

Restriction on depth of basis of erosion:

$$L_v + C_2L_o + C_3L_{ot} + n(C_4L_{kp} + C_5L_{ot}) \leq H L_s ;$$

$$C_1 = 0 ; 4) 0 \leq C_2 \leq h_{m1} ; 5) 0 \leq C_3 \leq h_{m1} ; 6) C_4 = h_{m2} ; 7) 0 \leq C_5 \leq h_{m2} .$$

8) Restriction on transporting ability of a stream

$$C_4L_{kp} - C_5L_{ot} \approx 0,$$

where L_v - Zone of concentration of a runoff (according to Figure 1); L_o - Zone of the beginning of loss; L_{ot} - Zone of adjournment of sediments; L_{kp} - zone of critical loss; C_i – factors, on physical sense corresponding average to the maximal depth of loss on a site; n – number of the periods of alternation of zones of critical loss and adjournment of sediments. Depends on length of a slope, quantity and intensity of sediments, agricultural background and etc.; L_s – length of a slope; H – falling of a slope; h_{m1} – The maximal depth of loss in a zone to corresponding initial length of loss, a variable depending on a chemical compound of water, dynamics of a stream, characteristics of a spreading surface, etc.; h_{m2} – the maximal size of loss in a zone of critical loss, also a variable depending on dynamics of a stream, granulometric structure of soil, a chemical compound of water, etc.

The given system of the equations contains 3 unknown

persons defined empirical by (n, h_{m1}, h_{m2}) . In particular, the number of the periods can be defined under the following formula:

$$\begin{aligned} n &= X_1 X_2 X_3 X_4 X_5; \\ X_1 &= 10,04 + 7,52 \cdot 10^{-7} Ls^{3,0}; \\ X_2 &= 1,078 I_{\min} / (0,01166 + I_{\min}); \\ X_3 &= 1,179 - 0,001916 T_{nn}^{3,0}; \\ X_4 &= 0,8378 + 0,0004172 I_{\max} + 222,9 / I_{\max}^2; \\ X_5 &= 0,9771 + 0,00922 af, \end{aligned}$$

where I_{\max} - the maximal gradients on a slope, ‰; I_{\min} - the minimal gradients on a slope, ‰, T_{nn} - version soil and ground (3- chernozem ordinary on loess, 5 - chernozem ordinary on marl 4- chernozem ordinary on sand, 6- marl); af - agricultural background (1 - fall-plowed field, (winter crops, for snowmelt), 4 - rangeland, long-term grasses).

Relative error of model $E = 3,003$ %, absolute error of model $E_1 = 0,117$, coefficient of correlation $r = 0,999$, criterion of quality of model (criterion Gaus) $s/s = 0,049$.

In a slope the water-currents which have generated at snowmelts, it is possible to define the maximal depth (h_{\max} , m) of water on following empirical dependence:

$$\begin{aligned} h_{\max} &= X_1 X_2 X_3 X_4 X_5 X_6 X_7 X_8 X_9; \\ X_1 &= 0,04742 Ls / (89,09 + Ls); \\ X_2 &= 1 / (106,8 - 29,65 pHn + 2,071 pHn^2); \\ X_3 &= 1 / (1,519 - 0,3286 z_0 + 0,0375 z_0^2); \\ X_4 &= 1 / (0,9581 - 0,008324 Nan + 0,0006553 Nan^2); \\ X_5 &= 1 / (1,848 - 0,07068 Ic + 0,0009172 Ic^2); \\ X_6 &= 1 / (1,603 - 0,03258 lp + 0,0003012 lp^2); \\ X_7 &= 1,02 NO_3 n / (0,0002629 + NO_3 n); \\ X_8 &= 1 / (1,034 - 351700 \exp(-0,4985 Wn)); \\ X_9 &= 1 / (-0,1211 + 0,01266 XS - 0,00003358 XS^2), \end{aligned}$$

where Ls – length of a slope from a watershed up to gauge line measurements, m; Ic - gradients of a slope, ‰; pHn – acidity superficial 0-3 sm of a layer of slope; z_0 – depth of thawing of soils; Nan – The maintenance of sodium in the top 0-3 sm a layer of soils, mg/100 g; lp – depth frast soils, sm; $NO_3 n$ – The maintenance of nitrates in the top 0-3 sm a layer of soils, mg/100 g; Wn – Humidity of soils, ‰; XS – quantity of precipitation for the autumn-winter period (November-March), mm.

Relative error of model $E = 22,0\%$, absolute error of model $E_1 = 0,001$ m, coefficient of correlation $r = 0,88$, criterion of quality of model (criterion Gaus) $s/s = 0,48$.

As process of washout and accumulation is dynamical also places of the greatest washouts and adjournment vary depending on quantity of sediments, their intensity agricultural background, etc. it is necessary to spend a series of calculations for revealing zones of the most probable loss and adjournment of sediments. Besides at the long period of a runoff of a zone of loss tend to move regres-

sively on a stream^[29], that also can be considered empirically at consecutive recalculation.

Place of accommodation of the first construction will be a point above the top border of the possible beginning of loss. The place of the beginning of loss can be calculated also by any existing technique^[32] on the basis of comparison of achievement by a stream of washing away speeds or tangents of pressure, etc. Dependences for definition of speeds of movement of water and tangents of pressure in slopping water-currents for different kinds of a runoff are presented in the appendix.

Distances between the subsequent constructions on a slope should be counted in view of change silt charge and the charge of water on length of a slope and in view of volume reservoir at a construction, and also admissible washout on a site. However, basically, if to start with pre-conditions of techniques existing on today for calculation of the subsequent distances between constructions it is possible to use the same formula, as for definition of a site of the first construction from a watershed, believing, that the top construction serves as a watershed for the remained part of a slope and calculation is conducted from a new watershed.

The offered method is more dynamical and considers прерывность process, unlike available. The binding to length of a slope allows to use it at creation of projects of land tenure with application GIS - technologies.

At application of agrotechnical ways of protection soils from erosion also it is necessary to have in view of, that the sequence of a combination agricultural background on slopes also can serve as the reason of strengthening of erosive activity of streams of water on a slope. Especially it concerns long-term grasses and rangeland. The soils under these agricultural background freezes through considerably, and thaws more slowly, than on others agricultural background, the significant roughness of a surface creates conditions for accumulation of a snow at which thawing energetically active streams of water not counterbalanced by sediments flow down on a surface of a slope and if below these agricultural background settle down agricultural background with smaller antierosion stability intensive loss of soils is observed.

4. Conclusions

The led researches allow to recommend to add existing system of designing of antierosion constructions on slopes in system of the organization of territory of land tenure with following positions:

1. Accommodation of the first construction and on a slope is necessary for projecting the subsequent above a place of concentration of a runoff, instead of on it as it is

done now. As in this place washout of soil and destruction of a construction is most probable.

2. Distances between constructions are necessary for appointing in view of a chemical compound of water as on short sites of a slope which are created at construction of constructions, the chemical component can appear more significant, than dynamic.

3. It is necessary to consider a crop rotation planned for given territories and system of fertilizers corresponding it since application of fertilizers promotes increase beaching substances, and will influence stability of constructions.

4. Alternation agricultural background on a slope should correspond to admissible change of hydrodynamical characteristics of water-currents so that transition from one agricultural background to another was not accompanied by strengthening of powerful activity of water-currents.

The system of crop rotations and system of fertilizers can be considered in calculations using a balance method of calculation the offered V.P.Gerasimenko and M.V.Kumani^[13].

Advantages the soil- water-security organizations of territory of land tenure in adaptation of territories to changes of a climate consist in the following:

1) Long-term researches show maintenance of regulation maintenance with a moisture territories, creation of a favorable microclimate, preservation of fertility soils and a biodiversity vegetative and fauna;

2) At flooding the special organization of territory does not allow water to flow down quickly in downturn of a relief and it reduces peak of a high water, that is stretches a freshet wave that reduces losses from a high water, the water distributed on a reservoir sates the top layer of soils and a zone of aeration, providing vegetation with a necessary moisture, and also preventing loss of a fertile layer of soils, in agrarian landscapes we promote productivity.

3) Growth of vegetation provides a favorable microclimate, shading a surface of the soil, reducing its warming up and heating of asphalt-concrete designs in settlements, favorably influences clearing of atmospheric air of dust and other polluting substances, etc.

The complex system of the organization of territory of land tenure will allow to reduce amplitude of fluctuations of heat and a moisture in problem territory and by that will lower probability of their flooding, loss, deficiency of water and desertification.

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