



Assessment of the Erosion Stability of Slopes in Terms of Digression and the Degree of Overgrowth

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Abstract: Agroecological systems of slopes experience stress due to constant dynamic movements, especially on the slopes of high steepness. We have formulated the idea of critical levels in the dynamic process of slope agroecological systems, which is subsequently considered as an indicator of sustainability. When analyzing the dynamic processes on the slopes, we identified the digression of the slope surface under the influence of erosion processes as a critical one. The object of research is the erosion slopes of ravines and gullies in the forest-steppe conditions of the Volga upland. The purpose of the study is to develop parameters for assessing the stability of erosion slopes based on the results of research and analysis of literature sources. Results and discussion. It is proposed to refer to the dynamics changes not only in species composition, but also changes in the degree of degradation in terms of overgrowth of slope areas, allowing to establish the processes of secondary succession as the destruction of the slope surface. According to our concept the changes of species diversity on the erosion slopes may be accompanied by the appearance of alien plants in consequence of the stability, biological diversity and protective functions of the protective forest plantations loss. The number of species may increase, but the erosion slope gradually loses its stability. Quantitative assessment of the degree of overgrowth in terms of undergrowth and their qualitative characteristics give an idea of compliance of the forest conditions on the slope with environmental requirements for self-seeding tree species. It is found that the number of self-seeding on the slopes with increasing stage of digression naturally decreases. The number of self-seeding, compared with seedlings, 2-4 times less, regardless of the degree of digression of the slope. On the control and on the site of stage I of digression, the number of shoots of self-seeding clearly differ, which affects the incidence rate. In other areas, the occurrence is 53 -100%, which confirms the uneven of overgrowing of the slope area.

Keywords: Assessment, Slope, Stability, Digression, Degree of Land Overgrowth, Undergrowth, Self-Seeding

1. Introduction

The problems of slope land resistance to erosion are fundamental in modern agroforestry, but so far the definition of sustainability remains ambiguous. The sustainable functioning of agro-ecological systems is inextricably linked to the concept of critical condition. The concept of critical state is interpreted in different ways. L. Zhukov and co-authors [1] define a critical state as a irreversible change in the existing conditions, leading to a violation of the organization of this system. Danilov-Danilyan V [2] indicates that in a critical state the ecosystem is being rebuilt with the replacement of some or all elements, after which its complete

disintegration may follow, or Vice versa, the formation of a new homeostatic level may occur. In the absence of dynamic movements of the biotope, critical condition may be due to climatic anomalies (drought, flood, etc.) or natural disasters, for example, fires [3].

The dimensions of land degradation are alarming; it affects from 30 to 50% of the earth's land surface. In some areas the productivity of eroded soils cannot be restored, even with heavy applications of fertilizers and other fossil energy inputs. Soil erosion reduces the valuable diversity of plants, animals, and soil microorganisms. [4]. Land areas covered by plant biomass, living or dead, are more resistant to wind and water soil erosion and experience relatively little erosion because

rain drop and wind energy are dissipated by the biomass layer and the topsoil is held together by the biomass [5]. The effects of soil erosion on crop productivity are not only local or regional concern but also global problem owing to finite soil resources. Therefore, accurate estimates of soil productivity and soil erosion are significantly important for sustainable land resources planning [6].

Agroecological systems of slopes experience a state of stress due to constant dynamic movements, especially on the slopes of high steepness. Down the slopes there is a movement of loose masses of debris, and the nature of the movement is determined by the steepness of the slope, the composition of its constituent rocks and factors affecting the slope. It is sharply manifested in the amplification of surface runoff [3]. We have formulated the idea of critical levels in the process of the dynamics of slope agroecological systems, which is subsequently considered as an indicator of sustainability. Analyzing the dynamic processes on the slopes, some authors identify the second stage of digression as critical, while others, on the contrary, do not see the critical level of disorder in the processes of autoregulation (self-renewal of the edifier). There is a great deal of discussion and debate on the role of dynamics of species composition in the process of destabilizing the natural ecosystems. At the same time, there is a strong opinion that the loss of a certain part of the species diversity (up to 10-20% of the initial cenosis) leads to the destruction of a particular ecosystem. However, Titlyanova [7] believes that it is the species structure that has the least resistance and the first to react to perturbation, when the entire ecosystem is sufficiently constant in species composition and does not lose stability. Zhukova L. A., Polyanskaya T. A. [8] in this regard, it is noted that only highly dynamic and sustainable ecosystems can survive in stressful environmental situations. The biological diversity existing in any ecosystem is directly related to the amount of living and non-living organic matter present [9-13].

2. The Object of the Research

The object of the research are erosion slopes of ravines and beams in the conditions of forest-steppe of the Volga upland erosion on the slopes of the Ilyinsky district forestry Republic of Chuvash-Volga district, a Rootkit forestry of the Republic of Mari El and Volga sub-area and Novocheremshanskaya forestry TSIL'ninskaya district of Ulyanovsk region-Kubnya - bulinski subdistrict. On the territory of Ilyinsky forestry objects of research were shadow and light slopes, derived from agricultural turnover. The slopes are devoid of woody vegetation, grass cover is represented by grasses and are characterized by varying degrees of digression. The slope of the shadow and the exposure length 74,4 m, the slope is 32°. Slope, solar exposure, with a length of 160 m, a slope of 34°. On the territory of a Rootkit of forestry of the Mari El Republic, the slopes are represented by agricultural unused overgrown land. The steepness of the slope of the solar exposition – 29°, length – 184 m, the steepness of the shadow slope – 43°,

length – 74 m. the Slope at the bottom is covered with a solid dense turf. In the Novocheremshansky forestry of Tsilninsky district of Ulyanovsk region, the slope of the solar exposition with a length of 38 meters has a steepness of 17°, the section of the watershed plateau – up to 30° is characterized by a different degree of digression. Artificial anti-erosion plantations of Scots pine on the area of 1.2 hectares, age 9 years, have been created in the slope zone.

3. The Aim of the Work

The aim of the work is to develop parameters for assessing the stability of erosion slopes based on the results of research and analysis of literature sources.

4. The Subject of the Study

The subject of the study is the assessment of the stability of slope lands in terms of digression and degree of overgrowing of slopes.

5. Material and methods

Trial areas were laid in accordance with the industry standard (OST 56-69-83. Square forest inventory. Bookmark method) [13]. The stages of digression were determined by the degree of destruction (decrease in power or disappearance) of the upper most fertile soil horizons as a result of water and wind erosion. To assess the stage of degrassie we used transactie method, which is based on the determining of the relation of disturbed area of ground vegetation to the total area of the surveyed slope. At the same time, the length of the area disturbed by erosion was measured on the running lines evenly covering the surveyed area, and it was correlated with the total length of the running lines. Their length at an error of 0.1%, was 500m per hectare of the surveyed area. According to measurements and corresponding calculations, four stages of digression and control were distinguished: the first stage included areas where the area disturbed by planar erosion is 15-30%; the second – 30-45%; the third-45-60%; the fourth - more than 60%; – parts of the slope grassing or occupied by protective plantations, without signs of damage served as a control. In addition, for the sustainability assessment we used the rate of natural revegetation of slopes on the area of size 1 x 1 m, in an amount not less than 25 pieces on each slope by the method of A. V. Pobedinsky [14] by the number of self-seeding or regrowth. Test sites were laid in such a way as to cover the entire investigated area of the slope from the edge to the valley to the ravine. Also we evaluated the uniformity of the self-sown young growth and undergrowth on the sloping surface. The uniformity of distribution was estimated by the index of occurrence, by dividing the number of accounting sites occupied by self-seeding and adolescents to the total number of sites per unit area. In the scientific literature, a number of authors propose to assess the stability of a biocenosis in terms of the vital status of plants [15-17]. The vital state of the undergrowth

was assessed according to the method of V. A. Alekseev [16], pointing out 4 categories of plant state: healthy, weak, withering and withered. The calculation of the life state was carried out according to the formula:

$$L = \frac{100n_1 + 70n_2 + 10n_3}{N}$$

Where: L-the relative life state of the undergrowth; n_1 , n_2 , n_3 – the number of healthy, weakened and withering trees per 1 ha, respectively; N – the total number of undergrowth, including dry, per 1 ha. With $L = 100-80\%$, the slope area was assessed as stable, at $79-50\%$ – the stability was weakened, at $49-20\%$ – the stability was strongly weakened and below 20% – the unstable slope.

6. Results and Discussion

It is not enough to assess the sustainability of protective forest plantations on slope lands only by indicators of changes in the composition and structure of plants. It is necessary to expand the classical understanding of changes, without limiting to the study of the species

composition of trees and shrubs and herbaceous vegetation with the dynamics of the degree of representation of individual species. We propose to refer to the dynamics of changes not only changes in species composition, but also changes in the degree of degradation in terms of overgrowth of slope areas, allowing to establish the processes of secondary succession as the destruction of the slope surface. According to our concept, the changes of species diversity, erosion on slopes may be accompanied by the appearance of alien plants in consequence of the stability loss and loss of biological diversity and protective functions of the protective forest plantations. The number of species may increase, but the erosion slope gradually loses its stability.

Quantitative assessment of the degree of overgrowth in terms of undergrowth and their qualitative characteristics give an idea of compliance of the forest conditions on the slope with environmental requirements for self-seeding tree species. These data show that the number of self-seeding on the slopes with increasing stage of digression naturally decreases (table 1; Figure 1).

Table 1. The overgrowth of the plots of the slopes depending on the degree of digression.

Stages of digression	Number, thous. ind. /ha			Frequency, %			Ambundance, ind. /ha ²		
	seedlings	self-seeding	undergrowth	seedlings	self-seeding	undergrowth	seedlings	self-seeding	undergrowth
control	120	72	1,7	100	88	10	11	3,2	1,0
I	80,1	33,1	12,8	100	100	44	5,2	3,6	1,5
II	56	19	9	100	100	48	2,9	2,1	1,6
III	44	11	5,4	80	65	42	2,5	2,4	1,0
IV	26,2	9,3	3,4	93	53	38	2,1	1,1	1,0

This is due to the removal of minerals from the soil surface as a result of plane erosion, violation of the integrity of the living ground cover and deterioration of soil and environmental conditions for plant growth. It can be concluded that the degree of overgrowth of slopes depends on the degree of digression of the slope surface.

The number of self-seeding, compared with seedlings, 2-4 times less addicted from the degree of digression of the slope.

On the control and on the site of stage I of digression, the number of seedlings, self-seeding clearly differ, which affects the incidence rates. In other areas, the occurrence is 53 -100%, which confirms the uneven overgrowing of the slope area. The vital state of the undergrowth determines the success of the formation of plantations on the slopes (table 2). Depending on the slope exposure, vital signs vary.

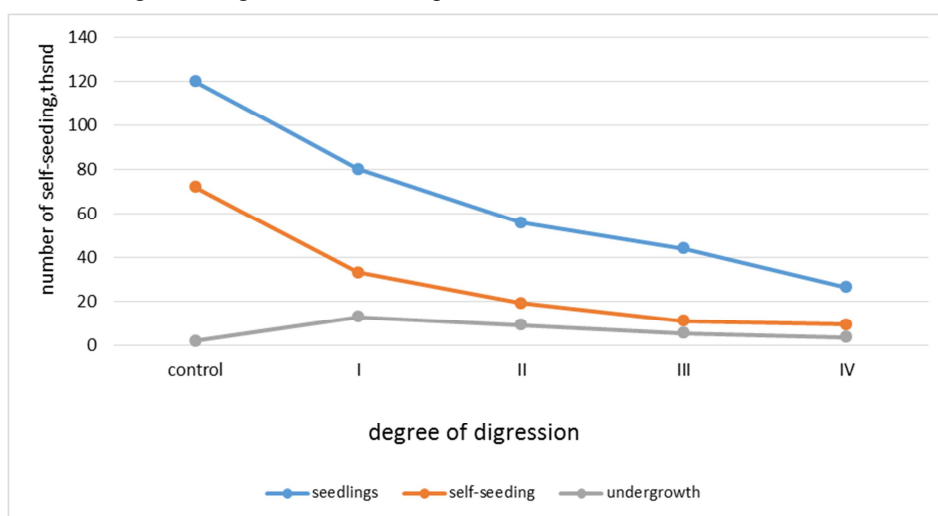


Figure 1. Changes in the number of trees during slope overgrowing depending on the degree of digression.

On the example of pilot areas in forestry of Ministry of natural resources of the Chuvash Republic the dependence of the vitality of the undergrowth from the slope of the exposure is clearly seen (Figure 2). On the southern slope the number

of healthy undergrowth is almost 2 times less than on the Western slope. This pattern is preserved in all soil-ecological sub-regions of the forest-steppe of the Volga upland (Figure 3).

Table 2. State of undergrowth* of woody plants in soil and climatic sub-regions.

Names of the subareas of the study and exposure of the slope	The actual number of undergrowth in the sample areas, (units.)				Relative state of life, %
	total	healthy	weakened	dry	
Ilyinsky district forestry of the Chuvash Republic of the Volga district					
Southern slope	657	353	148	156	71,9
Northern slope	682	476	80	126	79,9
Eastern slope	712	548	78	86	85,8
Western slope	794	586	152	56	87,9
Rootkinskiy forestry of the Republic of Mari El and Volga sub-area					
Southern slope	621	327	142	152	71,1
Northern slope	645	412	78	155	74,7
Eastern slope	697	443	64	190	72,7
Western slope	734	453	68	213	71,1
Novocheremshanskaya forestry of Tsilninsky district of Ulyanovsk region-Kubnya - Bulinski subdistrict					
Southern slope	432	256	113	63	79,0
Northern slope	564	297	124	143	70,6
Eastern slope	575	302	69	204	64,5
Western slope	546	305	100	141	71,3

*The undergrowth in height not less than 1.0 meters.

The areas presented in the study, except for the Eastern and Western slopes in the Ilyinsky district forestry of the Chuvash Republic, belong to the weakened slopes in terms of stability.

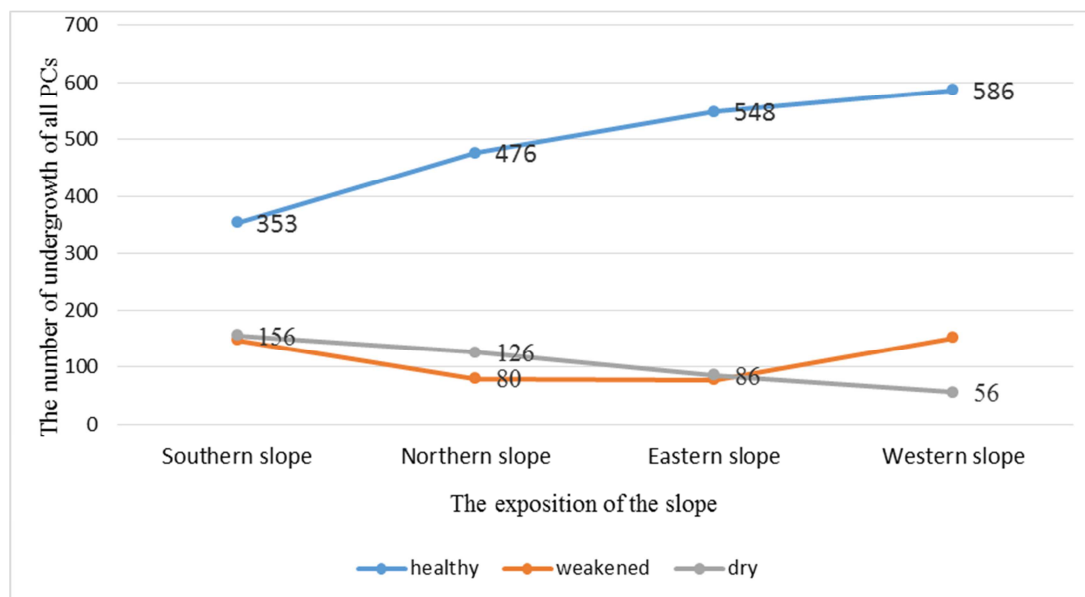


Figure 2. The life state of the undergrowth on the slope expositions in the Volga region (Chuvashia).

The amount of dry and weakened undergrowth on the southern slopes is much higher compared to the Western and Eastern slopes.

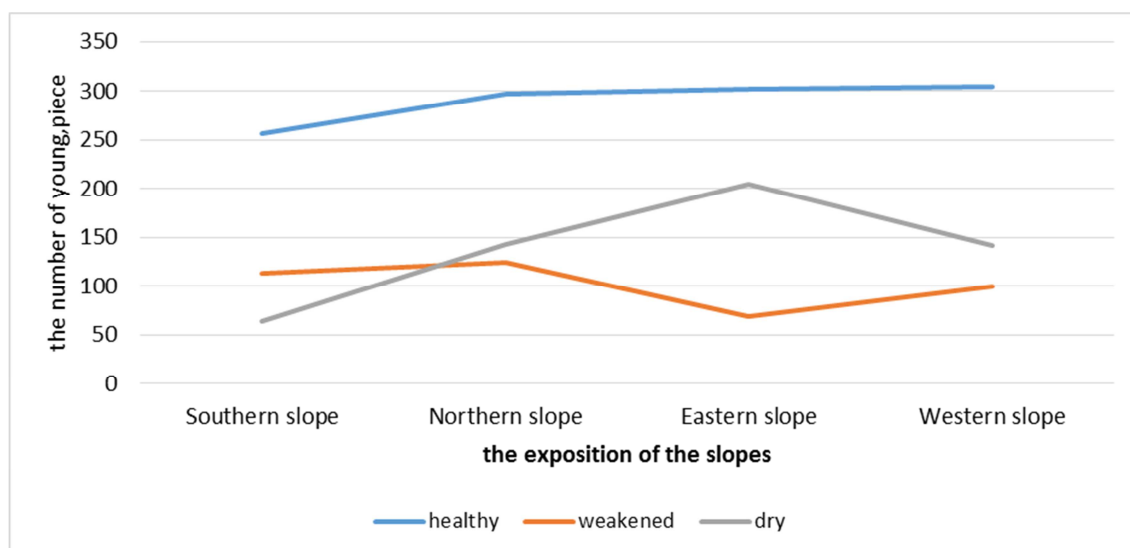


Figure 3. The life state of the undergrowth on the slope expositions in the Kubnya-Bulinsky sub-district (Ulyanovsk region).

It should be noted that the number of weakened and dry trees in total is 70.4% of the total number of undergrowth on the slopes of the southern exposure in the Kubnya-Bulinsky sub-district (Ulyanovsk region), while this figure for the Chuvash Republic is 26.8% (Volga sub-district).

Conclusions. The conducted researches allow to draw the following conclusions:

1. There are four stages of slope digression: the first stage includes areas where the area disturbed by plane erosion is 15-30%; the second stage – 31-45%; the third stage – 46-60%; the fourth stage – more than 60%;
2. At high rates of self-seeding, the number of plants at the stage of germination and undergrowth on the slopes vary depending on the stage of digression of the slope surface;
3. The ratio of healthy, weakened and dry plants varies depending on the exposure of the slope and forest area in the forest-steppe of the Volga upland. On the light slopes (southern and Western exposure) the number of dry and weakened undergrowth reaches 70%, and on the shadow slopes (Northern and Eastern exposure) within 21-29%, which can be an indicator of the stability of the slopes.

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