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Research Article

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Differentiation of altitude-vegetation geosystems, taking into account the calculations of vegetation indices to improve the soil erosion monitoring system

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Abstract.
Vegetation cover is one of the main factors that cause soil erosion. The lack of permanent vegetation cover leads to extensive soil erosion. Since loose, dry, bare soil is the most susceptible to the erosion process. The article provides material on the possibilities of calculating the vegetation indices NDVI and SAVI using remote sensing images of the research object for 1990, 2000, 2010, 2022. The results of the research made it possible to analyze the state of the flora distributed in the study area, as well as to develop measures aimed at protecting the flora. Based on the analysis of the vegetation cover, it can be concluded that for tree and shrub vegetation, the following were taken as the main features for assessing the soil-protective capacity: the crown density of the tree and shrub layer and the condition of the forest litter and ground cover.

Key words: soil erosion, vegetation index, vegetation cover, remote sensing.

Introduction.

Vegetation cover plays a special role in monitoring soil erosion. The state of vegetation cover and litter is an informative indicator of erosion hazard. High density and good condition of vegetation indicate a low risk of erosion (and vice versa) [1]. The litter absorbs water 5-10 times its weight and prevents surface runoff [2]. Vegetation cover is a key parameter in soil-ecological monitoring studies [3, 5, 8] and in soil erosion assessment studies [4, 6, 7]. Since the 1970 s, approaches to monitoring vegetation cover by remote sensing have been developed. One of the most developed areas of use of remote sensing materials and soil erosion monitoring is the development of the theoretical and applied concept of radiation reflection from vegetation cover. The concept of using remote sensing is reduced to the systematic measurement of a certain part of the electromagnetic spectrum and the interpretation of detected anomalies based on differences in the properties of the object under study.

Purpose of the study.

Differentiation of altitude-vegetation geosystems based on calculations of the normalized difference vegetation index (NDVI) and the soil-corrected vegetation index (SAVI) in order to improve the soil erosion monitoring system.

Material and methods of research.

In the course of the study, we used generally accepted methods such as remote sensing, comparative analysis, monitoring, monographic research, field, laboratory and in-house research. GIS packages such as ArcGIS Desktop/Workstation, Arc/Info, ArcView, and others were used to process remote data. ArcView The ERDAS software for pixel classification was also used

Research results and their discussion.

The object of research is the territory of the Zaamin mountain juniper Reserve. The territory of the reserve is located on the slopes of the Turkestan range and consists of well-formed regional mountain ranges located at an altitude of 1760-3500 meters above sea level and located in the highlands. The reserve has three vegetation zones: foothill, forest and subalpine. The foothills are located at an altitude of 1300 to 2300 meters above sea level. The woodland starts at an altitude of 2100 meters and reaches a height of 2700 meters. Three types of fir trees grow in the object of research: Zaravshan, Hemispheric and Turkestan. Hemispherical spruce forms joint forests with Turkestan firs at the top of the slopes and at the bottom with Zaravshan firs. Forest vegetation in this zone plays a very significant role in inhibiting the development of erosion in this region. This is explained by the fact that the forest cover serves as an obstacle to water flushing (with the help of the root system), reducing the speed of flushing, changing the direction of water flow, breaking the water flow into separate weaker streams. But on the other hand, being located in closed depressions, kolki (small forest) accumulate snow not only under the woody vegetation, but also on the slopes of the depressions bordering it. Here, when the turf is damaged due to overgrazing during periods of snowmelt and heavy rains, fine earth is washed away, accompanied by the formation of fine linear forms oriented to the center of the depression, as the basis of erosion. Naturally, on well-heated exposures of slopes with the same amount of precipitation, conditions are created for the development of xerophytic vegetation, the belt of which can rise up the slope, displacing less xerophytic, and vice versa. A characteristic feature of the woody vegetation of the mountainous territory is sparseness. On vast territories, there are isolated scattered trees, individual sparse or closed stands, alternating with treeless areas. Depending on the complex of natural factors, the anti-erosion effect of plants can be divided into three periods.

In the first period, which lasts from the end of December to the beginning of March with a strong, and at the end of the period with a weak manifestation of erosion processes, the main anti-erosion role is played by the root system, forest floor and remnants of herbaceous vegetation. The root system of tree and shrub vegetation, densely intertwined, contributes to the formation of a strong lumpy and nutty soil structure, increasing its anti-erosion resistance and water permeability, thereby reducing soil erosion. At the beginning of the growing season, the forest floor is almost non-existent, and in high-density stands in March, its capacity is insignificant and silt is almost nullified. The projective cover formed by trunks and branches cannot completely protect the soil from erosion, although under forest stands the water permeability of the soil is high and they greatly reduce the force of raindrops. The amount of precipitation during this period is insignificant and they mainly fall in the form of snow, most of which is absorbed into the soil during thawing. The second period (March-April) coincides with the maximum amount of precipitation in the form of showers, when the soil is poorly protected by vegetation. The rate of precipitation is greater than the rate at which runoff is absorbed into the soil, resulting in surface runoff that washes away the soil. In addition, the interval between rains is insignificant, and the soil, being in a wet state, is easily eroded. It is during this prairie that the maximum surface runoff and soil washout are observed. In the third period (May-October), when the projective cover and leaf surface reaches their maximum values, precipitation falls very rarely, mainly of a torrential nature and in most cases does not cause surface runoff and soil washout, since the soil is protected from erosion.

Remote sensing is based on the wavelengths of reflected light, not on direct contact with the observed object. Among many methods, there are methods of relationship models based on regression analysis of remote sensing data, or rather calculations of various vegetation indices NDVI and SAVI. Calculations based on the NDVI and SAVI indices for remote images for 1990, 2000, 2010 and 2022 can be seen in the following figure (figs.1, 2).

Fig1.

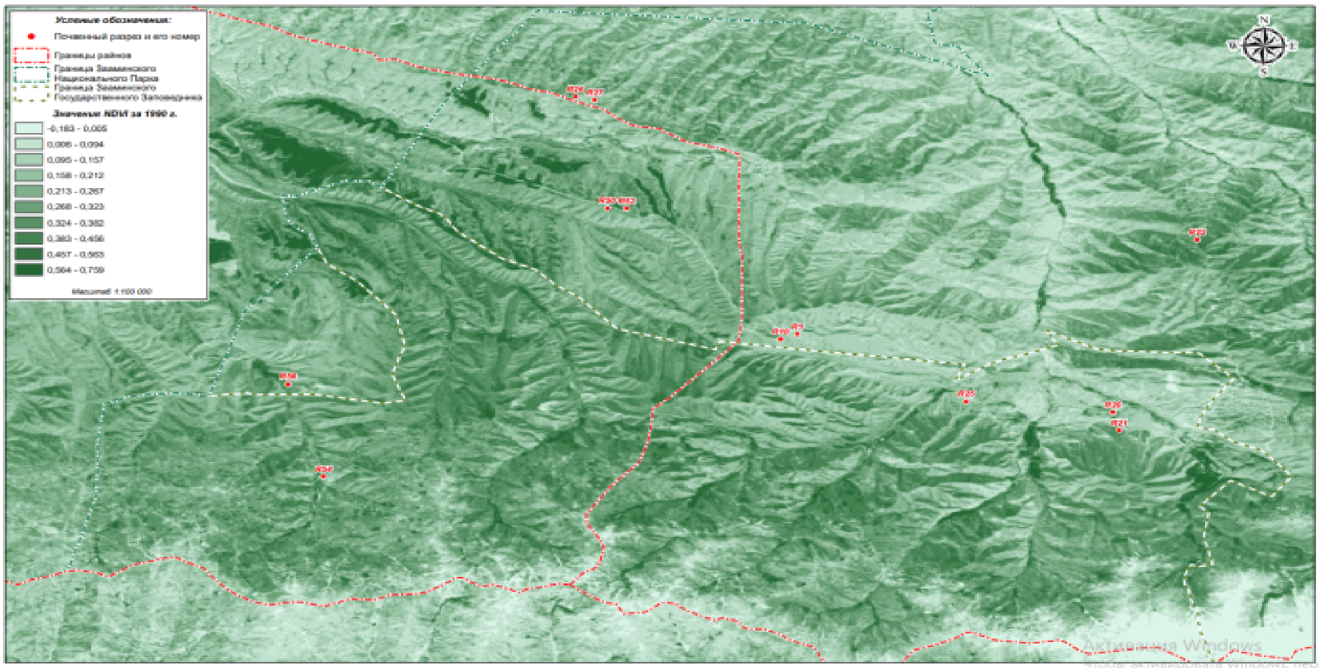

Fig.2.

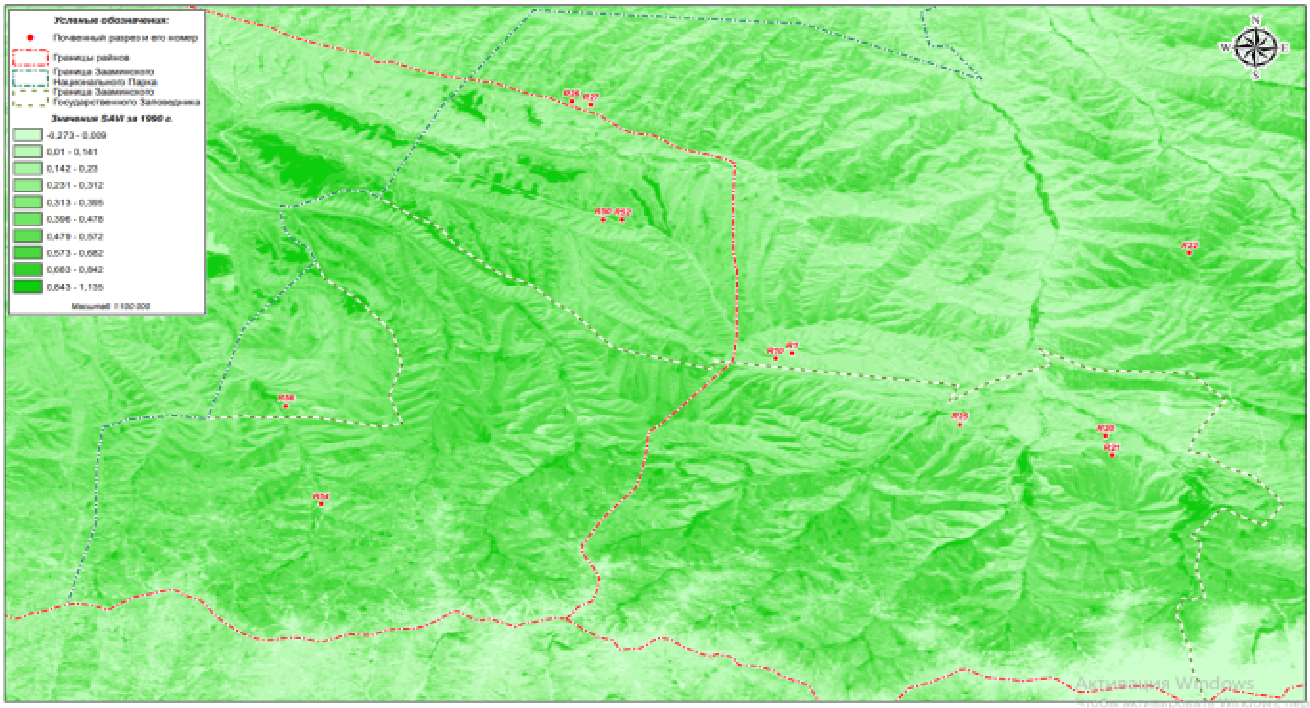

Fig1.1

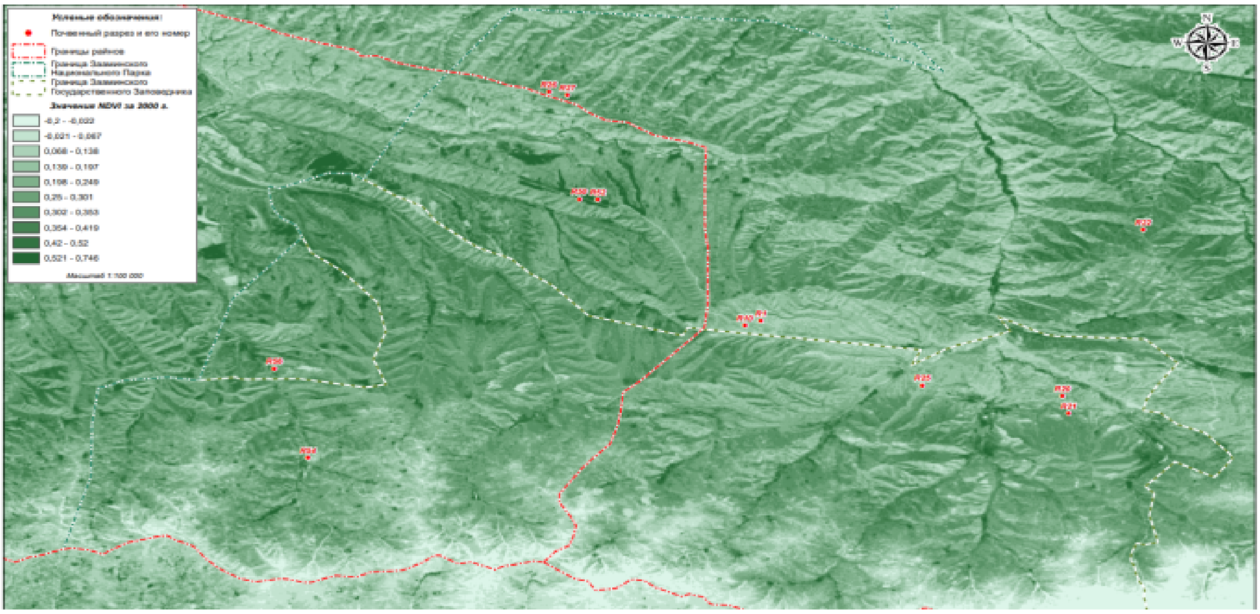

Fig.2.1

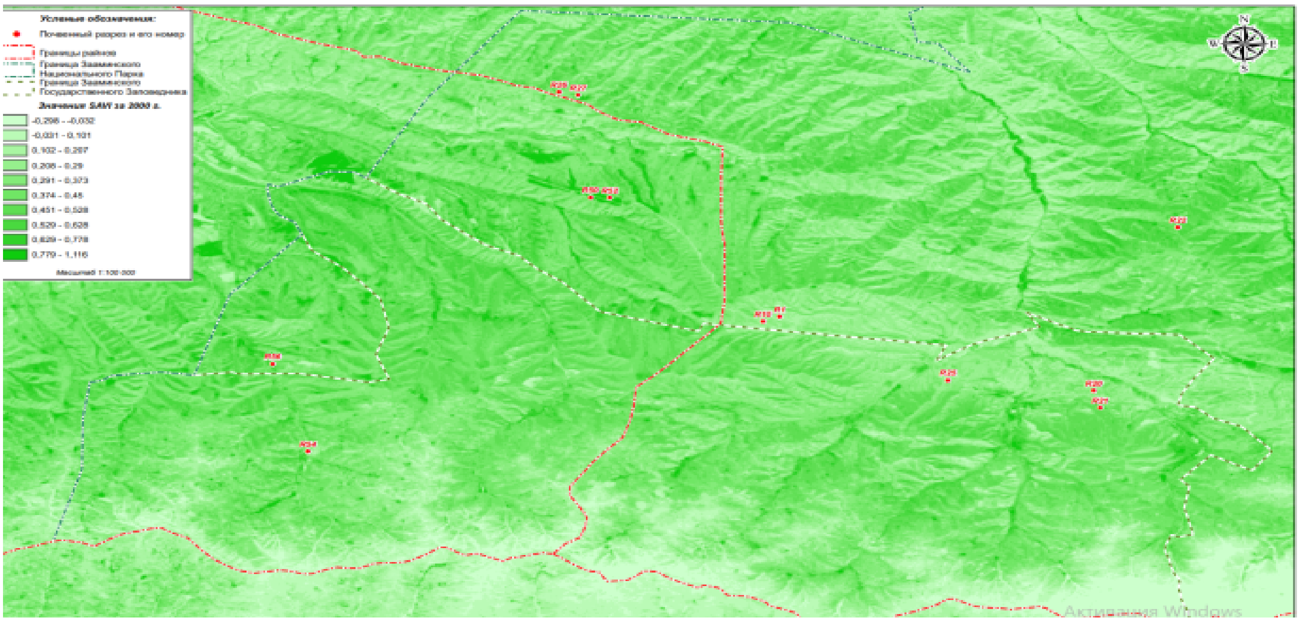

Fig1.2

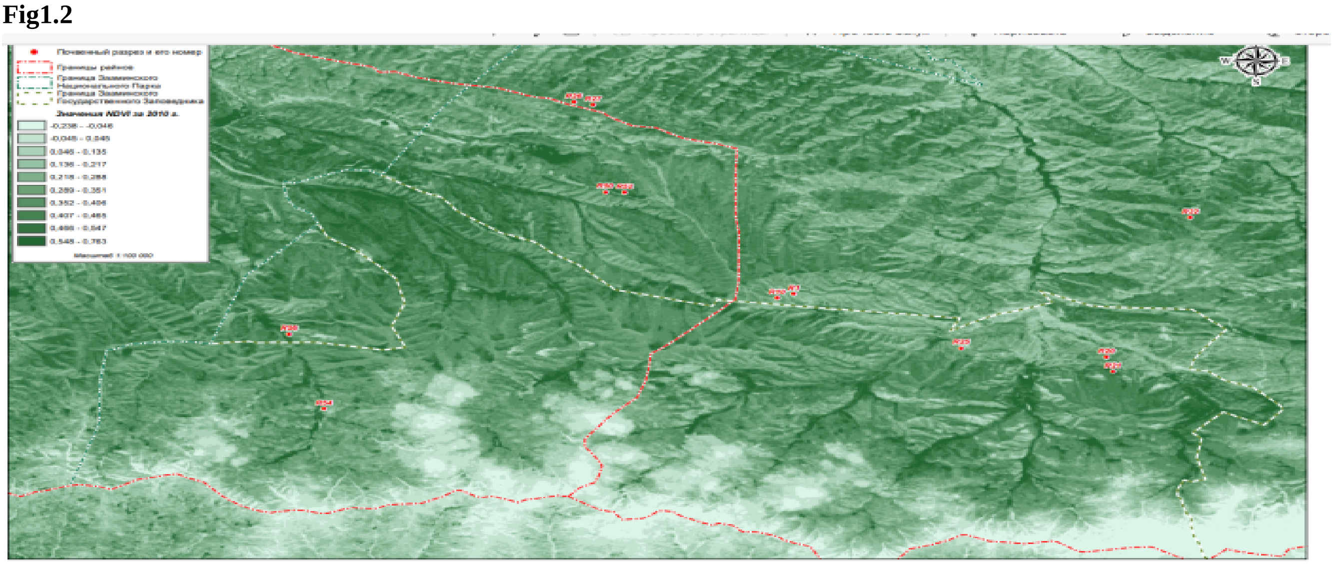

Fig.2.2

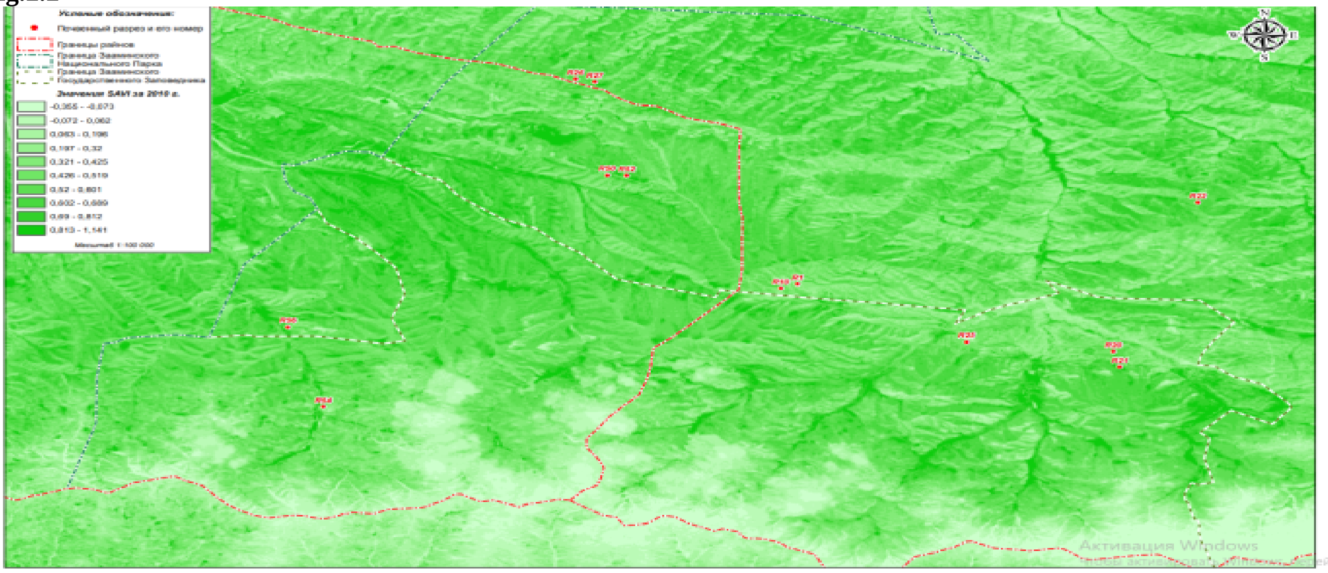

Fig1.3

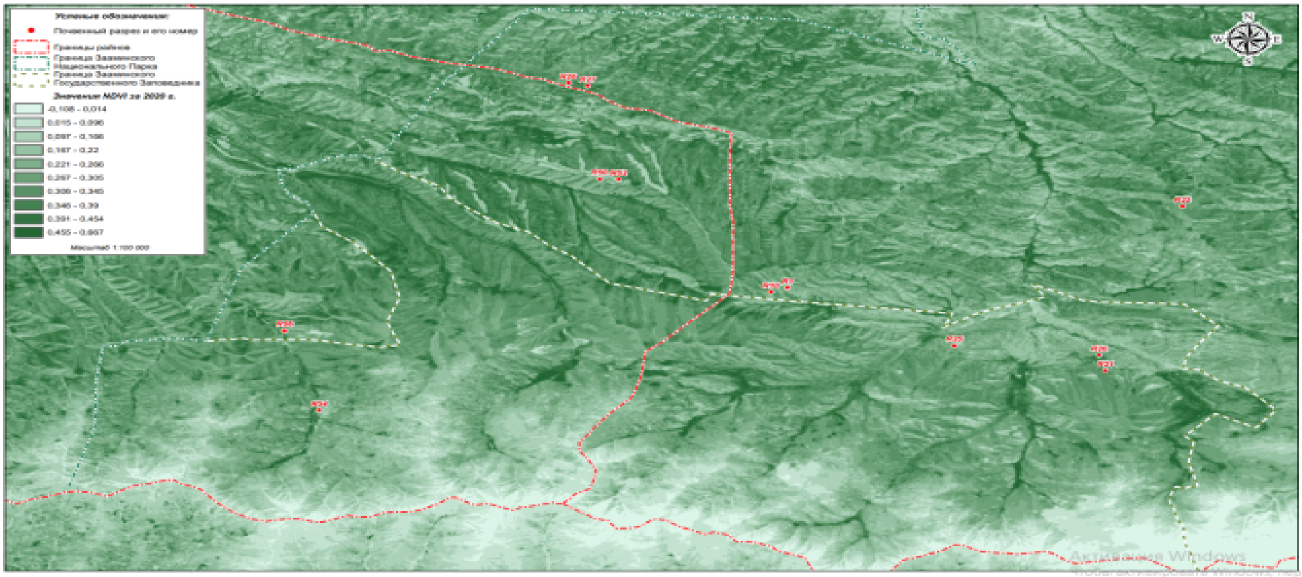

Fig.2.3

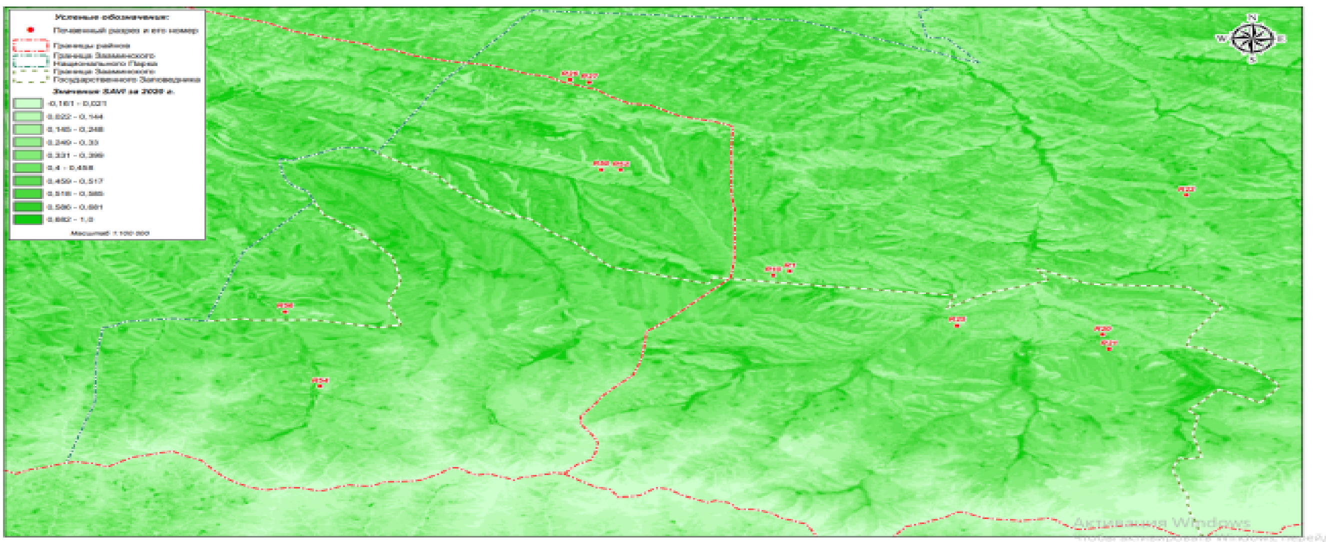

Fig.1-1.3. Calculations of the NDVI index for images for 1990, 2000, 2010, 2022 years.
Fig.2-2.3. Calculations of the SAVI index for images for 1990, 2000, 2010, 2022 years.

Negative index values are mostly associated with clouds, snow, and water. The near-zero values are mainly due to rocks and bare soil. Values from 0 to 0.1 correspond to sand, snow, or empty rock areas. Values in the range 0.2 to 0.3 represent shrubs and grasslands, while values in the range 0.6 to 0.8 indicate temperate forests. As we know, plants have chlorophyll, which absorbs sunlight for photosynthesis. Chlorophyll strongly absorbs visible light (0.4 to 0.7 microns) for photosynthesis, while the leaf cell structure strongly reflects near-infrared light (0.7 to 1.1 microns). If the plant is healthy, it will have a large amount of chlorophyll on the leaves and will absorb a good amount of visible light from 0.4 to 0.7 microns and reflect it to a much lesser extent, and vice versa (Table 1).

Table 1. Empirical correspondence between the vegetation index value and the type of ground cover

Values of the index	Covering characteristics
in the range of 0.81-1.0	correspond to different degrees of closeness of stands
in the range of 0.59-0.80	Correspond to areas where a fairly dense vegetation cover is formed (herbaceous or shrubby varieties of plant culture). This category of the index belongs to such natural-territorial complexes as the transient zone and high-mountain meadow communities.
within 0.39-0.58	areas with weak closure of the tree tier or low woodlands. This zone can be attributed to the transition zone from steppe and semi-desert landscapes, as well as in low-altitude and sometimes middle-altitude areas, where the transition of vegetation communities from mountain-forest to mountain-meadow occurs.
in the range of 0.2-0.38	they have a fairly large area of the studied territory, and these areas are characterized by landscapes with shrubby, sparsely woody vegetation. This type of landscape is mainly used for southern, sunny, and solar exposures. In the faces of this type of landscape, medium-mountain and steppe meadow-steppe plant cultures are distinguished.
in the range of 0.09-0.19	open soil, typical for low mountains and foothills, where they correspond to areas with steppe and semi-desert vegetation, widely represented within the territory. Along with herbaceous plant crops, there is a wide distribution of shrubs, agricultural land (fields, vineyards and pastures). Calculations of vegetation indices for the object of research can be seen in the table

For a more detailed analysis, it is necessary to calculate the coverage area of each value (Table 2, 3).

Table 2. Results of calculations of areas covered by vegetation cover vegetation index NDVI

NDVI criterion	Coverage area, %			
	1990	**2000**	**2010**	**2022**
0,18-0,00	1,89	3,04	3,51	3,02
0,00-0,09	8,09	5,01	4,63	4,96
0,09-0,15	15,94	10,05	5,20	6,68
0,15-0,21	17,20	16,26	8,87	10,81
0,21-0,26	17,67	18,4	13,56	16,69
0,26-0,32	15,64	20,46	17,58	19,81
0,32-0,38	11,86	15,85	19,5	19,7
0,38-0,45	7,72	7,57	16,49	11,79
0,45-0,56	2,73	2,28	8,07	4,77
0,56-0,75	1,23	0,91	2,47	1,64

Table 3. Results of calculations of areas covered by vegetation cover vegetation index SAVI

SAVI criterion	Coverage area, %			
	1990	**2000**	**2010**	**2022**
0,27-0	1,90	3,07	**3,29**	**3,02**
0-0,14	8,20	5,04	4,66	4,96
0,14-0,22	14,93	10,17	5,15	6,68
0,22-0,31	17,12	15,17	8,60	10,81
0,31-0,39	17,7	19,75	13,2	16,69
0,39-0,47	15,84	20,51	17,3	19,81
0,47-0,57	12,70	15,68	19,5	19,7
0,57-0,68	7,61	7,40	17,01	11,7
0,68-0,84	2,68	2,24	8,53	4,77
0,84-1,13	1,23	0,93	2,62	1,64

As can be seen from the analysis of the obtained materials, the research area differs significantly in vegetation. There is a mountain forest within which various plant groups are distinguished. The results of calculating the indices were compared with the data of field studies and it was found that the lower part of the vegetation of the object of research is represented by a shrub-grass association: wheatgrass (Agropyrum trychophorum), bulbous barley (Hordeum bulbosum), bonfire (Bromus sp.), bluegrass (Poa bulbosa), from the shrub honeysuckle (Lonicera sp.), rosehip (Rosa sp.). Juniper forests or woodlands occupy mainly dry slopes in the middle part of the belt, rising in some places to the upper border. They are formed by the Turkestan juniper (J. turkestanica), which is represented by tree-like and creeping forms. Juniper woodlands alternate with open slopes with mixed grasses-steppe, mainly wheatgrass-barley associations, and in the upper part of the belt large grasses from Prangos pobularia Ferula. Further up in the zone of light brown meadow-steppe soils Festuca, Festuca tianifolia, Poa bulbosa, Ranunculus pseudohirculus, and Carex melanantha develop under low-grass vegetation. They are even higher developed in more humid areas near springs and snowballs under lute-sedge-bluegrass vegetation Ranunculus pseudohirculus, Carex pseudofoetida, Poa alpine, etc. The high-altitude meadow-steppes of the study area are monotonous and poor in species composition. In addition to sheep fescue (Festuca ovina), here you can find tonkonog (Koeleria gracilis), oats (Avena desortorum) and some other cereals. Only on moist soils can you see other vegetation. It is mixed with various Alpineplants: primrose, gentian, geranium, buttercup, which gives some similarities with Alpine lawns.

CONCLUSION.

Based on the analysis of the data, it can be concluded that for tree and shrubby vegetation, the following criteria were taken as the main features for assessing soil protection capacity: the closeness of the crowns of the tree and shrub layers and the state of the forest floor and ground cover. The vegetation is meadow-steppe, with a large participation of various grasses and shrubs, in some places - juniper, spruce, apple, individual walnut trees. This territory has an almost undisturbed plant community with good soil protection capacity. Also, the highest percentages of projective coverage with high blackening are typical. High - and medium-resistant species participate in the herbage. Communities in this category do not require special restoration measures (except for minor insolated eroded slopes). All that is required is their rational use. From the above, it can be said that the soils distributed on the shadow slopes, with the exception of eroded differences, always have a thick fine-earth cover, and this at one time does not contribute to the formation of surface runoff. Therefore, these plots are the best land in mountainous areas. Plant communities with minor signs of disturbance: reduction in the percentage of blackening (with still sufficiently high projective coverage) and introduction of weakly erosion-resistant species. There is also a weak severity of erosion processes (with the exception of eroded insolated slopes). These lands require partial surface improvement with regulated use. Vegetation of this category needs partial reforestation measures aimed at increasing crown closure and restoring the tree litter, as well as favorable conditions for the natural renewal of woody vegetation. Naturally, all plant communities need protection, continuous reforestation measures and the promotion of natural regeneration.

The period of greatest precipitation falls on March-April, and the maximum projective cover of the soil is observed from May to November. During this period, the minimum amount of precipitation is observed, and in summer they are completely absent, that is, at the moment of maximum precipitation, that is, at the moment of maximum precipitation, the leaves on the trees are completely absent. These features of vegetation cover have a significant impact on the processes of soil formation, since vegetation is the main source of energy material for soil formation. The most dangerous conditions for flushing are created on backgrounds with sparse vegetation. Here there is a constant application of flushing, as well as mutual complementation and provoking water erosion.

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Conflict of Interest: No potential conflict of interest declared.

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