Risk identification and assessment of irrigated land erosion in Tashkent province, Uzbekistan

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Abstract. Irrigated fields are important assets for agricultural development since they supply vital food and fiber to people all over the world. These areas are, however, also susceptible to erosion, which can result in the deterioration of the soil and a loss in production. It is crucial to identify and evaluate the erosion risk in irrigated areas in order to maintain sustainable agriculture and guarantee the resources' long-term availability. The objective of this study is to create a thorough system for recognizing and evaluating the erosion risk in irrigated areas. The methodology will take into account a number of variables, including climate, topography, soil properties, land management techniques, and other pertinent variables that affect the risk of erosion. To identify and assess the erosion hazard of irrigated lands of the farm named after. S. Rakhimov of the Chinaz district of the Tashkent province, Uzbekistan, we laid 4 key sites, depending on the steepness, length, slope exposure and sown crops, and mapped the soils at a scale of 1:1000. At each site, profiles were laid that sequentially cut all the elements of the slope, from the top to the plume, and all soil varieties found on this slope. In the alignment of the profiles, on all elements of the relief, 25 reference sections were laid, characterizing all soil varieties in this area. To identify the boundaries of the contours of individual soil varieties, a series of hollows and pits were laid. Soil morphology was studied on the reference sections, and soil samples were taken according to genetic horizons for subsequent analysis.
Keywords. Remote sensing, machine learning, soil salinity map, salinity index

1 Introduction

Irrigated lands are critical resources for agricultural production, providing essential food and fiber for populations around the world [1]. However, these lands are also vulnerable to erosion, which can lead to soil degradation and a decline in productivity. Identifying and assessing the risk of erosion in irrigated lands is essential to maintain sustainable agriculture and ensure the long-term availability of these resources. This study aims to develop a comprehensive methodology for identifying and assessing the risk of erosion in irrigated lands [2]. The methodology will consider various factors such as climate, topography, soil characteristics, land management practices, and other relevant factors that

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contribute to erosion risk [3]. The results of this study will provide valuable information to farmers, land managers, and policymakers, enabling them to make informed decisions about land use and management practices to reduce erosion risk and maintain the productivity and sustainability of irrigated lands. Ultimately, this study will contribute to the development of sustainable land management strategies that promote food security, environmental conservation, and economic development [4].

The degradation of irrigated lands is a significant problem in many regions of the world, including Tashkent Province in Uzbekistan [5]. Erosion caused by wind and water can lead to a decrease in soil fertility and productivity, negatively affecting agriculture and the livelihoods of local communities. To address this issue, it is essential to identify and assess the risk of land erosion in the region [6]. This study aims to analyze the factors contributing to erosion and to develop a comprehensive risk assessment methodology to help local authorities and farmers make informed decisions about land management practices. By understanding the extent and severity of the erosion risk, it will be possible to develop effective mitigation strategies and ensure the sustainable use of irrigated lands in Tashkent Province.

Soil protection from erosion is especially relevant for Uzbekistan, since the area of land subject to erosion is 1,772,300 ha, or 40% of the total area of arable land in Uzbekistan (data from the Ministry of Agriculture of the Republic of Uzbekistan, 2021). The urgency of these problems also lies in the fact that every year the problem of increasing the productivity of agricultural crops on irrigated lands of the Republic of Uzbekistan becomes more and more acute [7]. The Tashkent region is one of such regions of Uzbekistan, where erosion processes are most common. The study of the erosion hazard of irrigated lands and their qualitative assessment is of particular importance in connection with the further intensification of agricultural production and more rational economic use of lands in various sectors of the national economy.

2 Materials and methods

Below are descriptions of 4 key areas that are most typical for the full disclosure of the categories of erosion hazard of irrigated lands on the farm [8-10].

The key site-1 was laid out on an irrigated typical serozem, cotton field, southern exposure, and slope steepness - 3-0. Length - 150 m. The soil cover consists of 3 soil varieties, moderately eroded, strongly eroded and reclaimed. The total area is 6.45 hectares.

The key site -2 is laid out on an irrigated typical serozem, cotton field, and eastern exposure. The soil cover consists of 3 soil varieties: slightly eroded and reclaimed. The steepness of the slope on the weakly eroded parts of the slope is 1-0, and on the moderately eroded parts of the slope it is 3-40, the length of the slope is 110 m.

The key site-3 was laid out on an irrigated typical serozem, a cotton field with a western exposure, slope steepness - 5, length - 300 m. The soil cover consists of two soil varieties, the total area is 11.2 ha.

The key site-4 was also laid on an irrigated typical serozem, cotton field, northern exposure, and steepness 10, slope length - 100 m. The total area is 5.4 hectares.

In these key areas, the amount of soil washout during furrow irrigation was determined depending on the steepness, length, and slope exposure. Determining the amount of soil washout was carried out using the Thomson weir.

Numerous studies have shown that the supply of irrigation water to loosened dry soil at a rate higher than the critical one always causes soil washout [11, 12]. The high erodibility of loosened serozems is manifested not only due to the genetic characteristics of the soils of the sierozem belt (low water resistance), but also due to the separate-partial state of the arable layer and the erosion of dry aggregates and lumps by trapped air when they are

abruptly immersed in a water flow. The role of the trapped air is that, having a low solubility in water, it contracts when the aggregates are immersed in water, and sharply increases the pressure. When the pressure force exceeds the binding force of soil particles in the aggregates, they break and the crushed particles are pushed up by the pinched air, which increases their removal.

If water, flowing down on the surface of virgin soil, first separates the soil particles and aggregates bound together and only then causes them to be washed away, then on arable soil the main energy of the water flow is spent on flushing the already separated particles and aggregates.

Washout and erosion of serozems proceeds most intensively at the beginning of irrigation. Gradually decreasing towards the end, when the main part of the arable layer of soil has already been demolished. This is explained by the fact that soil aggregates and particles of the underlying layers have time to be moistened by capillary action and become more resistant to washout and erosion. The well-known rule is based on this - to start watering on the slopes with a small jet, and after some moistening of the soil surface, increase the flow of water into the furrow.

The soil, as the uppermost shell of the earth's surface, is in close relationship with the terrain. As you know, relief refers to one of the five main factors of soil formation. Irrigation water from elevated relief elements is removed downward along the inclined plane of the slopes. It should be noted that part of the water moves in the soil and ground layer. Forming an internal slope runoff, which has a great influence on the redistribution of hyperkinesis products over the relief elements. The magnitude of surface and underground runoff depends mainly on the steepness of the slope, the state of the soil surface, its composition, and the nature of the vegetation cover. In this regard, on different slopes, soil erosion of different magnitudes occurs.

In identifying and assessing the erosion hazard of irrigated lands, from our point of view, from the relief elements, the steepness, length of the slope, as well as their exposure are of the greatest importance. The vegetation factor also has a significant effect on the amount of irrigation soil washout.

3 Results and discussion

The results of our research show that when irrigating along furrows, more fine earth is washed away from slopes of more than 50% compared to slopes located less than 2-30 degrees. From key area 3 (slope steepness 50) 103.0 t/ha of fine earth was washed away per year, key area No. 1 (slope steepness 30) - 78.5 t/ha per year, key area No. 4 - 18.8 t/ha, and from key plot No. 2 - 54.0 t/ha (Table 1).

When determining the category of erosion hazard of the studied key areas, we used the “Scale for determining the category of erosion hazard of irrigated gray soils” compiled by Elyubaev and Nurmukhamedov.

The lands of the key area No. 1 on this scale turned out to be very dangerous, the lands of the key area No. 3 - very strongly dangerous, the lands of the key area No. 4 - slightly dangerous and the lands of the key area No. 2 - medium dangerous.

To compile the map "Erosion hazard of irrigated lands" of the farm, we used the results of research and, in addition, the following materials.

1. Guidelines for the assessment and mapping of erosion-prone irrigated lands of the serosive belt;
2. Soil map of the farm, compiled by the Uzgiprozem Institute, M 1:10000;
3. Topographic maps, M 1:10000.

Table 1. Washout of soil from the ground surface, t/ha.

#	Average steepness of slopes, in gradient	Amount of slopes, m	Slopes exposure	Culture	Average soil flush				In a year	Erosion risk category
					Irrigation I	Irrigation II	Irrigation III	Irrigation IV		
1	7^0	100	North	Cotton	8.6	6.0	3.0	1.2	18.8	Weak
2	3^0	100	East	Cotton	19.2	21.2	9.2	4.4	54.0	Moderate
3	3^0	150	South	Cotton	30.2	21.5	16.3	10.5	78.5	Severe
4	5^0	300	West	Cotton	33.6	37.2	18.2	14.0	103	Extreme

The rate of soil formation for different types of soils is different. In the soils of the serozem belt cut by loess, the process of soil formation proceeds quite intensively. We believe that the annual amount of flushing should not exceed the soil formation rate of serozems, equal to 10.

With a total area of the farm's territory of 2671.2 ha, non-erosion hazardous lands (plain) occupy 286.9 ha (11%), slope plumes (washed soils) 340.7 ha (13%). Slightly erosive watersheds 204.7 ha (8%), slightly erosive lands 95.0 ha (3%), highly erosive lands 1003.0 ha (37%), very highly erosive lands 150.5 ha (6%), catastrophically erosive lands 25, 0 ha (1%) and unvalued land 370.7 ha (14%).

Below is a general description and recommendations for soil protection from erosion by categories of erosion hazard:

I category of land - there is no danger of erosion, they occupy the flat part of the farmer's territory. The soils are irrigated typical serozems, heavy and medium loamy, unwashed, the relief is calm. These soils are more humus-rich and better supplied with nutrients than other categories; the leveling off the field surface is normal. Slope steepness - < 10, possible soil runoff acceptable (ie less than 10 t/ha per year).

One of the main measures to increase the productive capacity of soils in this category is the introduction of cotton-alfalfa crop rotation. The main type of soil cultivation is autumn plowing, which contributes to the accumulation of moisture and the fight against weeds. Especially great harm is caused by root cereals - humai, adzherik. Herbicides must be used to control them. For this purpose, once every 3-4 years, mid-depth plowing is carried out up to 50-60 cm without seam turnover. To obtain a high yield (35-40 quintals/ha), it is necessary to apply additional organic and mineral fertilizers.

Irrigation should be carried out in irrigated typical gray soils in 4 periods according to the 1:2:1 scheme (the first watering - during budding, the next two - during flowering and fruit formation, and the last watering - at the beginning of ripening) (Table 2).

Table 2. Scale for determining the category of erosion hazard of irrigated gray soils.

Erosion risk land category	**Soils**	**Soil-forming rocks**	**Relief**		**Possible annual washout, t/ha**
			Gradation by surface slopes	**Slope steepness,C^0**	
1- no risk of erosion	Meadow-oasis, irrigated, meadow, meadow-marsh, gray-earth-meadow and gray-earth-oasis	Alluvial and loess deposits	Plain	$<1^0$	<10
1^a – ditto	Irrigated serozems, reclaimed	Loess deposits	Plume	$<1^0$	Runoff accumulation
II – weak risk	Irrigated gray soils are slightly and medium loamy	Ditto	Watersheds	$1\text{-}2^0$	10-30
II ^{a} - ditto	Ditto	Loess, sometimes proluvial deposits	Slight slopes	$1\text{-}2^0$	10-30
III – moderate risk	Irrigated gray soils medium and strongly washed away	Ditto	Moderate slopes	$2\text{-}3^0$	30-55
IV- severe risk	Irrigated gray soils medium and strongly washed away	Loess deposits	Severe slopes	$3\text{-}5^0$	55-85
V- extreme risk	Ditto	Ditto	Extreme slopes	$5\text{-}8^0$	85-120
VI – cataclysmic risk	Ditto	Ditto	Cataclysmic slopes	>8	>120

I^a category of land - there is no danger of erosion, spreading on the plume of the slope, where the runoff accumulates and the formation of washed soils. The soils are powerful (thickness of the humus horizon A + B, more than 75 sec), in most cases humus and normally provided with nutrients, have some negative physical properties (waterlogging, compaction). In some areas, these soils are subject to varying degrees of salinity. Watering should be carried out 3 times according to the scheme 1:1:1. Irrigation rate should be 3000-3500 m3/ha. The main measures here should be of an ameliorative nature, since these soils are prone to salinization.

II category of land - low risk of erosion, occupies watersheds and upper parts of slopes, soils - irrigated typical gray soil. These soils are low in humus and contain an insufficient amount of nutrients.

Here it is necessary to apply the measures that are recommended in the first category. In addition, 30-40 t/ha of manure, 300 kg/ha of nitrogen, 125 kg/ha of phosphorus and 50 kg/ha of potash fertilizers must be applied to these lands. Irrigation should be carried out 5 times according to the scheme 1:3:1 at the rate of 4000-4500 m^3/ha.

Improper irrigation contributes to the manifestation of irrigation erosion. Therefore, on these lands, irrigation should be carried out using the smallest jets of water, it is also

necessary to apply chemical and agrotechnical measures that increase the erosion resistance and fertility of eroded soils.

II[a] category of land - low risk of erosion, relief - gentle. Here it is also necessary to apply those measures that are recommended in the first category, and in addition it is necessary to carry out plowing and sowing along a slope or along the smallest slope. Along with this, on the slopes, it is necessary to increase and maintain the anti-erosion resistance of soils at a high level in every possible way. A good effect in this regard was given by wetting the bottom of irrigation furrows with polymer K-9, chlorella. Sowing green manure crops (perco mixed with rye), introducing bentonite clays to the bottom of irrigation furrows.

III category of land - the average danger of erosion, the relief - slightly sloping. To prevent soil erosion, it is necessary to apply all types of anti-erosion agents described above. Soils of this category are poor in organic matter, the amount of which on the prevailing area does not exceed -0.58% (arable layer). Therefore, increasing their fertility is primarily associated with an increase in humus potential through the introduction of manure and various substances.

One of the cardinal ways to solve the problem of combating irrigation erosion and reproducing the fertility of irrigated lands is the introduction of crop rotations. Crop rotation schemes should be strictly differentiated, taking into account the category of erosion hazard of land. For highly erosion-prone categories, 4:3 or 5:4 schemes are recommended. As the erosion hazard of lands decreases, it is necessary to correspondingly reduce the proportion of the grass wedge in the crop rotation scheme. At the same time. On these lands, it is advisable to sow green manure crops with their further plowing into the soil.

IV category of land - a strong danger of erosion, the relief is sloping. In addition to the above measures, it is necessary to level the surface of irrigated plots by capital planning. At the same time, at least 40 t/ha of manure must be applied to the planned fields in the first year. These measures, as well as an increase in the norms of mineral fertilizers, will make it possible to cultivate technogenic-disturbed soils without noticeable crop losses. Of great importance are organic matter and sowing on planned plots of green manure crops, especially legumes. It is known that in fields with a surface slope of more than 3-0, furrow irrigation with even a very small jet of water leads to soil flushing. Therefore, the lands belonging to the IV category, it is advisable to gradually transfer to drip or subsoil irrigation. This method of irrigation is especially effective in areas where soils are underlain by saline deposits.

V category of land - a very strong danger of erosion, the relief is very sloping. Lands belonging to this category should be used for sowing fodder crops and planting orchards and vineyards. If these lands are used for row crops, then all precautions must be taken to avoid the undesirable consequences of irrigation erosion. In dry years, we propose to exclude these lands primarily from agricultural use in order to save irrigation water.

VI category of land - a catastrophic danger of erosion, the relief is steep. We proposed that these lands not be used for irrigated agriculture, since irrigating those leads to intensive development of irrigation and ravine erosion and removes the lands from agricultural use. In order to use these lands, it is necessary to carry out terracing and after that they can be used for planting fruit trees and vineyards (Table 3).

Table 3. Distribution of irrigated lands of the farm named after. S. Rakhimov on categories of erosion risk.

Erosion risk land category	Soils	Relief		Soil-forming rocks	Potential washout, t/ha	Area	
		Gradation by surface slopes	Slope steepness, C^0			ha	%
1- no risk of erosion	Irrigated typical gray soils, heavy loamy, not washed away	Plain	$<1^0$	Loess deposits	<10	286.9	11.0
1[a] – no risk of erosion	Irrigated typical gray soils, medium and heavy loamy, reclaimed	Plume	$<1^0$	Loess deposits	Runoff accumulation	297.5	11.0
II – weak risk	Irrigated typical serozems, medium loamy, slightly-medium eroded	Watersheds	$1\text{-}2^0$	Loess deposits	10-30	204.7	8.0
II[a] - weak risk	Irrigated typical serozems are medium loamy, slightly washed away	Slight slopes	$1\text{-}2^0$	Loess deposits	10-30	194.7	7.0
III – moderate risk	Irrigated typical gray soils, medium loamy, medium and strongly washed away	Moderate slopes	$2\text{-}3^0$	Loess deposits	30-55	95.0	3.0
IV- severe risk	Irrigated typical serozems, medium loamy, strongly washed away	Severe slopes	**$3\text{-}5^0$**	Loess deposits	55-85	1046.2	39.0
V- extreme risk	Irrigated typical serozems, medium loamy, strongly washed away	Extreme slopes	$5\text{-}8^0$	Loess deposits	85-120	150.5	6.0
VI – cataclysmic risk	Irrigated typical serozems, medium loamy, strongly washed away	Cataclysmic slopes	>8	Loess deposits	>120	25.0	1.0
Unaccounted for land	Homestead, cemeteries	Mounds, ravines, roads, canals, etc.	-	-	-	307.7	14.0
Total						2671.2	100

4 Conclusions

The irrigated lands of the lower reaches of the Chirchik River are erosion-prone to varying degrees. Erosion risk of irrigated lands located on this territory of the farm named after S. Rakhimov of the Chinaz district of the Tashkent province in Uzbekistan showed that 64.0% of the area of the economy are erosive. Of these, 15.0% are classified as saboerosive, 3% as moderately erosive, 39% as highly erosive, 6% as very highly erosive and 1% as catastrophically erosive. It was revealed that the reduction in the thickness of the humus layer of the soil, the deterioration of the water-physical properties of the soil, the decrease in the content of humus and nutrients occurs depending on the degree of erosion hazard of irrigated lands.

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