Islom Aripov, PhD researcher

Department of Ecology and Geography

Gulistan State University

LOSSES FROM BUILDINGS WATERLOGGING IN SETTLEMENTS OF SYRDARYA PROVINCE

Abstract. *This study examines waterlogging in settlements on saline soils in the Syrdarya province of Uzbekistan. The region's low relief makes areas vulnerable to waterlogging, often caused by irrigated agriculture. The research assesses the risks and damages to the population and infrastructure caused by this problem. Using risk assessment methods and social surveys, the study estimated the monetary damage to the populations of affected towns and cities and compared the cost of repairing roads in flooded saline and non-saline areas. The results show that about 60% of the urban population in Syrdarya Province have to carry out annual repairs to their homes due to waterlogging and salinisation, costing an average of $322.4 per household per year - almost equivalent to the average monthly salary in Uzbekistan. In addition, salinisation increases road repair costs by $68,750 per year per kilometre. To mitigate waterlogging, the study recommends the construction and effective management of drainage systems on affected lands and the implementation of cost-effective irrigation techniques.*

Key words: saline land, settlement, waterlogging

Introduction

Soil salinisation is a major factor negatively impacting agriculture, construction, and the environment in Uzbekistan. Approximately 2 million hectares, which accounts for 46.6% of the total irrigated area in the republic, are affected by salinisation to varying degrees. The primary cause of salinisation is the rise of the saline groundwater table (SGT) above the critical depth, which is due to high water losses from inefficient irrigation systems and unreasonably high irrigation rates in agriculture (Begmatov, 2020).

Salinity not only negatively impacts agricultural production but also has direct consequences for the population, including loss of business opportunities (both existing and potential) (Australia…, 2006):

- The loss of business, both existing and potential, should be considered
- The costs of rural restructuring when farms become unprofitable should also be taken into account.
- Additionally, increased health problems due to stress in families affected by change should be considered.

The indirect impact of salinisation on people is reflected in the reduced quality of the natural environment. Salinisation of lands and high groundwater table damages roads and bridges. In settlements, footpaths, parks, sewage pipes, residential buildings, and industrial constructions are also damaged.These phenomena result in substantial financial costs.

According to S. Wilson (2003), salinity damage caused by high aquifer salinity and saline water supplies in rural and urban areas can lead to increased repair and maintenance costs. For instance, the annual repair and maintenance cost of a sports stadium in a saline area is $5,000. Infrastructure life cycle costs can increase due to moisture and/or salinity damage, resulting in the need for earlier replacement. For instance, unpaved roads are typically renewed every 15 years, but in areas with saline soil, this period is shortened by 5 years, incurring additional costs for both the municipality and the community. According to Australian Report (Australia…, 2006), repairing infrastructure affected by salinity costs approximately $100 million per year in Australia. Negative impacts can be worsened in areas that are waterlogged. Waterlogging in urban areas can be caused by increased rainfall and building settlements in low-lying areas. Poorly developed drainage systems can also be a major cause, as they are often neglected during city construction (Yun-Fang Ning et al., 2017). Waterlogging in areas with saline soils can cause damage to buildings and structures due to the joint effect of water and salt. This damage can include harm to paint, wood, metal structures, and concrete (Aghimien et al, 2018).

D. Kosimova (2023) points out that during construction of industrial and civil structures on saline soils subject to waterlogging, inadmissible deformations and losses of bearing capacity of the foundation often occur. Accidental subsidence can be caused by leaks from water supply networks, leading to additional moistening of foundation soils and their uneven subsidence. There were cases of uneven suffosion subsidence of the foundation of a residential building, which caused cracks in the walls with an opening of up to 7 cm. The building was divided vertically into four compartments by these cracks, which required expensive repair works.

Negative impacts on infrastructure, particularly on motorways, have also been studied by a number of researchers.

For example, it has been found (Hudaykulov and Kayumov, 2021) that the presence of readily soluble salts in earth bed materials can cause failure of road surfaces, especially bituminous pavements. When the moisture content of the subgrade increases, soluble salts rise into the road surface layer, where they can subsequently crystallise, causing lifting and cracking of bituminous pavement and disruption of its adhesion to underlying layers. The thinner the surface layer, the greater the likelihood and extent of damage. Groundwater and surface water, which is retained in depressions of the relief, are the direct source of salt intake into the soil (Hudaykulov and Kayumov, 2021).

A. Kayumov et al. (2019) investigated the influence of the type of salinity and the amount of salt in soils on the calculated values of the indicators of subgrade soils of motorway subgrade. These researchers found that the presence of easily soluble salts in the earth bed has a negative confluence on the elastic modulus, adhesion force and other structural indicators of the road surface. It was found that in order to ensure the strength characteristics of roads with the content of 2-8% of easily soluble salts in the soil, it is necessary to increase the thickness of the pavement by 7...21 cm

R. Hudaykulov and A. Kayumov (2021), as a result of research conducted in Syrdarya province, established the negative impact of soil salinity on the evenness of the road surface.

All these negative impacts, of course, reduce the service life of road surfaces. The frequency of average road repairs on non-saline soils is 8 years (Radkevich, 2016); on saline soils 2.5 years, the cost of average road repairs is 250,000 USD/km (Kayumov et al., 2021).

Since the deterioration of the quality of buildings and roads has a negative impact on the living conditions of the population, it can be said that waterlogging of territories, especially with saline soils, is one of the types of geo-ecological risk for the population.

In Uzbekistan, the problem of assessing the impact of waterlogging and salinisation of settlements on social life has not been practically studied. Available studies are devoted only to the direct problem of groundwater table rise (Karimov et al., 2019, Mirzakhodjaev et al., 2018).

The purpose of this paper is to provide a monetary assessment of the risks to housing and roads in Syrdarya province associated with land salinity and waterlogging.

2. Methods

2.1 Geological and geographical information on flooded cities of Syrdarya province

The soils of settlements in Syrdarya province are saline to a greater or lesser extent and contain a certain amount of water-soluble salts, which determine the corrosivity of the soil environment in relation to concrete, steel and other building materials.

The amount of highly saline soils in Syrdarya province was in 2020 equal to 9,739 ha; in 2021 - 8,980 ha.

Syrdarya province is located in the lowlands, in the valley of the Syrdarya River (Fig. 1), therefore, there is a constant danger of flooding of settlements.

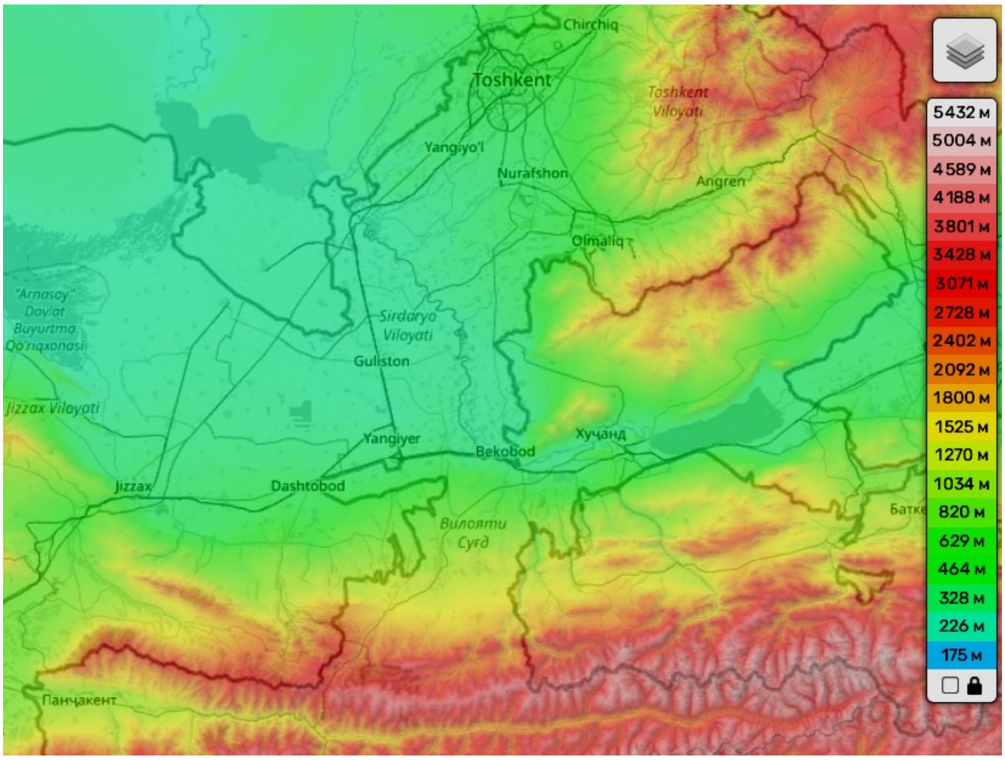

Fig. 1. Topographic map of Syrdarya province

(Source: https://ru-ru.topographic-map.com/map-s41qf3/Сырдарьинская-область/?center=40.40036%2C68.18316&zoom=8&popup=41.42489%2C65.58581)

Rising groundwater level due to poorly organised irrigation aggravates the situation and can lead to damage and even destruction of buildings and structures. A number of settlements in Syradrya province are in the waterlogged zone during the irrigation season.

The waterlogged towns include Gulistan, Syrdarya, Yangier and Shirin (Mirzakhodjaev et al., 2018; Karimov et al., 2019), but in addition to these relatively large settlements, many small settlements are located in the waterlogged zone. Let us give brief geological and geographical information about the mentioned towns.

The town of Gulistan is located in the old irrigated zone of the Hungry Steppe. Groundwater level regime is irrigation and depends on irrigation regime, first of all on canal discharge regime.

During the highest position, the groundwater table is at a depth of 0.5 - 1.0 m in the central part of the city and 1.0 - 1.5 m in its south-eastern and northern parts.

The lowest position of the groundwater table is observed at the end of the irrigation season. At the lowest groundwater level, groundwater occurs at depths ranging from 3.0 - 3.5 m in the zone of influence of the Dustlik canal to 2.0 - 3.0 m in the zone of influence of irrigation.

As a rule, groundwater is more mineralised far from the sources of supply and at the lowest positions of the level, and vice versa, less mineralised near filtration sources and during the summer growing season.

Soils of Gulistan in the depth interval from 0.2 to 2-3 m contain water-soluble salts in the amount from 0.2 to 4.4%, in srdenem 0.78% of dry weight. Type of mineralisation of aqueous solution of salts is sulphate-calcium.

The town of Yangiyer is located in the south-eastern part of the Holodnostepsky plateau. Groundwater mineralisation level is 1-2 m depending on the depths of draining collectors and distance from them.

Groundwater mineralisation and soil salinity are unevenly spread over the territory of the city. In areas with close groundwater table saline soils and solonts are developed, groundwater is highly mineralised.

Soils on the territory of Yangiyer town are of different salinity degree, with content of water-soluble salts from 0.565 to 3.180 %, average for the town is 2.140%.

The territory of Syrdarya city is located in the modern valley of the river of the same name, within its second supra-flood terrace.

Within the city territory the depth of groundwater occurrence at the maximum level position is from 0.5 - 1.0 m in the north and east to 1-2 m in the southern half of the city. In the east, south-west and in a small area in the centre of the city territory flooding occurs during the growing season. Groundwater level regime on the territory of Syrdarya is irrigation. The first maximum is observed in the period of leaching irrigation in February-March, the second maximum - in July-August - in the period of vegetation irrigation. The minimum position of groundwater table is observed at the end of autumn-winter period before the beginning of leaching irrigation. Annual amplitude of groundwater level fluctuation is 2.15 - 2.45 m.

Groundwater mineralisation is up to 980 mg/l in the vicinity of irrigation canals and up to 6,850 mg/l with distance from them (Sodikov and Agzamov, 2006).

Soils of Syrdarya territory have different salinity degrees. The content of water-soluble salts ranges from 0.29 to 2.75 per cent, with an average for the city of 1.32 per cent. Type of mineralisation of water-soluble salts solution of soils, as well as groundwater, is sulphate-hydrocarbonate.

According to the composition of salt components, both groundwater and soils of the cities under consideration are sulphate-aggressive to concrete and reinforced concrete structures on Portland cement, and in some areas - to structures on sulphate-resistant cement (Sodikov and Agzamov, 2006).

The length of motorways in Syrdarya province is approximately 900 km. The frequency of average road repairs on non-saline soils is 8 years (Radkevich, 2016); on saline soils 2.5 years, the cost of average road repairs is 250,000 USD/km (Kayumov et al., 2021).

2.2. Research Methods

As stated above, annual waterlogging by mineralised water causes significant damage to the buildings of settlements. The extent of this damage can be indirectly estimated by the average value of the annual costs incurred by residents to maintain their dwellings in an acceptable condition. Such an estimation was made in this study by social survey method (Likhacheva et al., 2017). The survey was conducted from May to October 2023.

Residents of large settlements represent a social community and can serve as a subject of sociological research. Usually, a continuous survey of such multiple communities is not possible due to economic and time constraints, so it is limited to a sample survey (Kelley et al., 2003; Xi Meng et al., 2015). The sample size for determining the share of some attribute X in the general population of more than 5,000 units is determined by the formula (Berezin, 2018, Gorodilin, 2006):

$$n_1 = \frac{1}{\Delta^2} \quad (1)$$

Where Δ is the value of acceptable error, it is taken equal to 5 % (0.05) with probability 0.954. In our case, "attribute X" is the share of residents of flooded settlements suffering from damage to buildings. The total number of residents of flooded towns is 167,000 people (Table 1). Thus, given the volume of the general population of 167,000 people, $n_1 = 1/0{,}05^2 = 400$ people. Consequently, to determine the share of residents who feel the impact of dampness on buildings, it is necessary to conduct a survey among 400 people.

Table 1. Information on the population of cities subjected to waterlogging

City	Population
Gulistan	90 000
Yangiyer	33 000
Syrdarya	27 000
Shirin	17 000
Total	167 000

Source: https://www.stat.uz/ru/ofitsialnaya-statistika/demography

The planning of the sample size for determining the numerical characteristics of the general population (e.g. average repair costs) is done as follows.

First of all, a sample survey is conducted (30 or more respondents). Then, based on the results of this survey, the sample size is determined according to the formula (Berezin, 2018; Paniotto and Maksimenko, 2017):

$$n_2 = \frac{\sigma^2 \cdot t^2}{d^2} \quad (2)$$

where: n_2 is the required sample size; σ^2 is the variance of the trait, the expected mean deviation of the obtained results from the expected mean value; t is the coefficient of the confidence level (2 - for 0.95, 3 - for 0.99); d is the level of accuracy for this factor.

The representativeness error is determined by the formula:

$$M = \frac{\sigma}{\sqrt{n_i - 1}} \quad (3)$$

Where $\sigma = \sqrt{\sigma^2}$ is the standard deviation, n_i is the number of pre-interviewees.

The marginal sampling error is determined by the formula

$$\Delta = tM \quad (4)$$

According to the survey data n_1=400 people about 60% of the population of the general population (100,200 people) have to make annual repairs of houses due to waterlogging. The remaining 40 per cent live in those parts of cities where the level of groundwater is low or on the upper floors of multi-storey buildings.

According to statistical data (Anon…, 2022), we take the average family composition of 5 people and determine the number of houses requiring annual repairs 100,200:5 = 20,040 houses.

To obtain data on the costs of annual repairs due to dampness, residents were asked a questionnaire including questions about the number of additional repairs caused by waterlogging and rising salts.

A preliminary survey was conducted among 42 residents. The level of accuracy d was assumed to be ±0.36 million UZS (10% of the arithmetic mean).

3. Result and Discussion

The results of the preliminary survey on annual repair costs are as follows (Table 2):

Table 2. Results of the preliminary survey to determine the sample size n_2

Number of preliminary respondents, people	Arithmetic mean of annual repair costs due to waterlogging, mln	Dispersion σ^2	RMS deviation σ	Representativeness error M	Marginal sampling error Δ	Required sample size n_2, people
42	3.5952	12.34	3.5134	0.5485	1.0974	≈ 380.6

Source: Developed by the authors

Thus, the sample size n_2=380 people was taken for the survey of residents.

The survey was conducted among residents of different settlements of Syrdarya province. The results of the survey are presented in Table 3.

Table 3. Results of the survey of residents of Syrdarya province suffering from dampness

Indicator	Value
Type of repair - major - medium - cosmetic	 21.3 % 46.8 % 31.9 %
Average number of repairs per year	1.3
Average cost of 1 repair, UZS million	3.1

Source: Developed by the authors

It can be seen from the above data that waterlogging of buildings in settlements causes different severity of damage to residential buildings. The average cost of one repair is UZS 3.1 million (about 248 USD), which, taking into account the average annual number of repairs of 1.3, gives a cost per household of UZS 4.03 million (322.4 USD).

Thus, the damage caused by waterlogging to the population of all cities subject to waterlogging is as follows:

$$D = 20040 \cdot 4{,}03 \cdot 10^6 = 80761{,}2 \cdot 10^6 \text{ UZS} = 6{,}62 \text{ million USD per year} \quad (5)$$

It should be taken into account that this calculation does not take into account smaller settlements.

Damage to roads due to salinisation of soils

On non-saline soils average repair is made once in 8 years (Kayumov et al., 2021), i.e. per year: 250,000:8 = 31,250 USD/(km·year)

On saline soils the necessity of average repair occurs on average once in 2,5 years, i.e.

250,000:2.5 = 100,000 USD/(km·year).

Thus, the damage to motorways is:

$$D_A = 100{,}000 - 31{,}250 = 68{,}750 \text{ USD/(km·year)}$$

For the whole length of roads:

$$D_{AT} = 68{,}750 \cdot 900 = 61{,}875{,}000 \text{ USD/year}$$

The obtained results show that the problem of waterlogging of settlements on the territory of Syrdarya province is markedly pronounced and has a serious impact on the welfare of the population, as the amount of costs for annual repairs exceeds the average monthly salary in Uzbekistan, which according to the State Statistics Committee of Uzbekistan in 2023 was about 319 USD.

The findings are generally consistent with the results of other researchers. For example, studies conducted by Nithila et al. (2022) for Bangladesh showed that the total flood damage for Dhaka city was estimated at about 48,500 USD for a sample size of 314 households. Moreover, the authors found that the magnitude of losses for high-income households is larger than for middle- and low-income households. The calculation shows that the average annual cost of additional repairs in Dhaka was 154.46 USD. This figure is half as much as the result for Syrdarya province, which can easily be explained by the different socio-economic situation and cost of repair materials in Uzbekistan and Bangladesh.

4. Conclusion

The conducted research has shown that in the Syrdarya province of the Republic of Uzbekistan there is a permanent geo-ecological risk of waterlogging of a number of settlements. This risk is expressed in additional expenses of the population for repair. The analysis of works of other researchers allows to recommend as the main measure of struggle the development and competent operation of drainage network in the zones subjected to waterlogging. It is also possible to recommend expansion of application of economical methods of irrigation. Measures to protect the base of buildings from salt corrosion and high humidity should be envisaged during construction. In the construction of motorways it is also recommended to organise the waterproofing of the base.

The values of the monetary risk assessment obtained in this study will allow economic justification of the necessary measures.

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