Assessing the Technical and Economic Efficiency of Improving the Ameliorative State of Saline Land: A Case Study of the Syrdarya Region

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Abstract. This article examines the economic efficiency of land reclamation measures for desalinating saline land, using the example of a hypothetical farm in the Syrdarya province of Uzbekistan. The evaluation method employed is the calculation of discounted costs. The results indicate that the payback period for works on weakly and moderately saline lands is 4 years and 3 years, respectively, with a net discounted income of $58,375 and $143,678 for the hypothetical farm under analysis. It is established that desalinisation of highly saline lands is unprofitable and they should be excluded from agricultural turnover.

1. Introduction

Soil salinisation is a major issue in agriculture worldwide, with particularly acute negative consequences in countries with agrarian economies. Uzbekistan is one such country, with a significantly developed agrarian sector that currently employs around 44% of the republic's labour force [1].

However, 45.3% of the republic's irrigated lands are subject to varying degrees of salinisation. Salinisation can significantly reduce cotton yields, with reductions ranging from 20-30% on slightly saline lands, to 40-60% on moderately saline lands, and even up to 80% or more on highly saline lands. High groundwater tables, inappropriate irrigation, and poorly maintained drainage systems can increase salinity levels, negatively affecting crop yields. This reduction in the resource base is estimated to cost approximately 1.0 billion USD annually due to land degradation processes [2, 3]. It is important to note that the use of clear and concise language, as well as the avoidance of complex terminology, can aid in the comprehension of technical information. These losses are often associated with a lack of timely and convenient information for public authorities to make correct decisions.

Land degradation and pollution are often caused by human activities, particularly illegal waste disposal [4], and the operation and use of road transport waste [5-8].

Soil salinisation is mainly caused by agricultural activity, which is strongly affected by salinisation.

The impact of salinisation processes on agriculture and other human activities can be seen in Syrdarya province. The economy of Syradarya province is predominantly based on agriculture, with a focus on cotton and wheat production. The province boasts a significant amount of irrigated land, accounting for 64.8% of its territory, located in the Hungry Steppe. However, 96.5% of this land is saline to varying degrees.

To maintain these lands in a condition suitable for growing crops, reclamation works on desalinisation are carried out. These works can consist of leaching irrigation, chemical reclamation, and organization of biofield, among others [9, 10]. To make a decision on reclamation works, it is necessary to have a preliminary assessment of the expected economic efficiency. These works require significant capital investments. According to the basic principle of environmental legislation, economic activity cannot be justified if the damage caused by it exceeds the benefit [11,

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12]. Ecological and economic efficiency of complex reclamation of saline or saline-prone lands, like all projects in the field of nature management, is assessed using net discounted income.

The economic efficiency of reclaiming saline lands should be viewed as a complex economic phenomenon. It reflects the ratio between the final results obtained in value form (gross, marketable, net production, profit) and the value and/or monetary (economic) assessment of the land and resources (production costs) that caused these results (effect). Several studies (11-14) have assessed the economic efficiency of land reclamation works, but they have only focused on one type of land reclamation or one type of salinisation. Furthermore, no estimates have been made for the conditions of Uzbekistan.

The purpose of this article is to estimate the expected efficiency of reclamation works on soil desalinisation with different salinity levels. This estimation will provide an opportunity for further planning of reclamation measures.

2. Materials and Methods

Since it is not possible to develop a full-scale project on soil desalinisation in Syrdarya province, the calculation is made for a certain conventional farm [14], the characteristics of which are given in Table 1.

Table 1. Characteristics of saline lands of a conventional farm

Area, ha	Soil types	Drainage requirement, m^3/ha	Type of land, cultivated crop	Yield, c/ha	Possibility of use
			1. Weakly saline soils		
1,500.0	Meadow, grey earth-meadow	No	Arable land, winter wheat, cotton	22-26 18-20	Suitable for intensive use after desalinisation measures
			2. Medium saline soils		
850.0	Meadow, grey earth-meadow	No	Arable land, winter wheat, cotton	15-16	Suitable for intensive use after desalinisation measures
			3. Strongly saline soils, solonets, malted soils		
3.5	Meadow, grey earth-meadow	50- 100	Pasture, mixed grass	12- 13 5-8	Limitedly suitable for cattle grazing
			4. Malts		
0.2	Turf and podzolic	-	-	-	Not suitable, subject to conservation

The economic efficiency of reclamation measures was assessed using the methodology outlined in [14]. This was based on the assessment of benefits from additional production resulting from land desalinisation. Accounting was made for both crop production, which resulted in a direct increase in crop yield, and livestock production, which resulted in an increase in fattening weight and milk yield due to pasture yield increase.

The economic costs were estimated by considering the following types of reclamation measures:

- for weak salinisation, surface washing should be carried out with a water consumption rate of 2-2.5 thousand m3/ha per year.

It is important to observe all rules of agrochemistry and carry out amelioration measures such as watering and loosening the soil.

- for average salinisation, surface leaching should be carried out with a water consumption rate of 2.5-3 thousand m^3/ha and repeated two to three times per year. Additionally, organic and mineral fertilizers should be applied, forest belts should be established, soil gypsum should be used, and phytomeliorative crop rotations should be organized with the selection of appropriate crops.
- In cases of strong salinisation, salts can be removed through mechanical methods [15]. If necessary, planning and repair works can be carried out on the drainage network. Chemical melioration and leaching irrigation (in winter or autumn, in several steps) can also be used. The leaching norm should be 3500 m3/ha and the quantity of leaching should be done two to three times per year. Soil gypsum can also be used, and phytomeliorative crop rotations should be organised.

The marketing research conducted allowed for the determination of the conditions and costs associated with the realisation of agricultural products. The cost of agricultural production for the given zone is calculated per 1 ton of cotton at $911 [17-18], forage wheat at $115.3, barley at $270, grasses at $80, milk at $940, and cattle meat at $8800.

Production costs on slightly saline lands are 30% of the cost of agricultural production, while on medium saline lands, they are 40% [14]. When determining the income from agricultural production growth on lands with varying degrees of salinisation, it is essential to consider the increase in crop yields as soils become desalinised.

The analysed farm achieves higher yields of main agricultural crops on non-saline lands. On average, this amounts to 55-60 centners/ha for winter wheat, 35-40 centners/ha for cotton, 40 centners/ha for natural pastures, 60-64 centners/ha for improved pastures, and 30-32 centners/ha for barley.
The cost of the work was determined based on the normative-information base of recent years. The analysis of cash flows in the project was conducted by calculating the cash outflows and inflows. The economic efficiency of the work was determined by integral indicators such as net discounted income, profitability index, and payback period of expenses for land desalination. Real money flows were calculated using the discount method, which involves bringing inflows and outflows of money to their current dollar value for the period under consideration.

3. Results and Discussion

As a result of researches and estimations the results of estimation of cost of land reclamation works and cash flows at desalinisation of lands with different degree of salinity were obtained.

3.1. Desalin All-Russian Scientific Research Institute of Automation named after N. L. Dukhovnyisation of slightly saline lands

These lands are characterized by reduced crop yields. Winter wheat yield is 22-26 centners/ha, cotton yield is 18-20 centners/ha.
Results of reclamation works cost calculation are presented in Table 2.
Assessment of income generation opportunities on slightly saline lands has shown the following. For lands where salinization is weakly developed, 7-field phytomeliorative crop rotation with average field size of 200 ha can be recommended: cotton → alfalfa → wheat → wheat → alfalfa → barley → alfalfa.

Table 2. Calculation of cost of works on desalinisation of slightly saline soils in a conventional farm (net area -1400 ha)

No	Types of work	Units of measurement	Number of units	Cost per unit, $	Total, $
		Hydrotechnical measures			
1	Conducting surface flushing (2 irrigations)	ha	1,400 x 2	10	2,800
		Organisational, economic and agrotechnical measures			
2	Construction of field roads	ha	7	250	1,750
3	Planting of forest belts	ha	28	300	8,400
4	Soil gypsumisation	tonna	602	10	6,020
5	Application of organic fertilisers (compost)	tonna	7,000	100	700,000
6	Application of mineral fertilisers	centner	2,325	2	4,650
7	Other costs for organisation of phytoreclamation crop rotations	ha	1,400	9	12,600
	Total	$	-	-	761,420
8	Coefficient that takes into account environmental factors	-	-	-	1.1
	Final total	$	-	-	837,562

The cash flow analysis is presented in Table 3.

Table 3. Analysis of cash flows in works on desalinisation of slightly saline lands

Calculation horizon (years)	Costs for desalinisation, $/ha	Cost of additional production, $/ha	Discount factor (interest rate 10%)	Discounted value of real money	
				Outcomes, $/ha	Incomes, $/ha
2022	80.20	-	0.91	72.98	-
2023	87.93	114.09	0.83	72.98	94.69
2024	97.44	116.19	0.75	73.08	87.14
2025	71.88	115.90	0.68	48.88	78.81
2026	78.42	115.32	0.62	48.62	71.50
2027	86.74	115.37	0.56	48.57	64.61
2028	95.66	115.38	0.51	48.79	58.84
Total	598.26	692.24	-	413.90	455.59

Net discounted income for 7 years will be $58.375. Profitability index will reach 1.1, cost recovery period will be 4 years.

3.2. Desalinisation of medium saline lands

Yield of agricultural crops is low (wheat 20-24 centners/ha, cotton 14-18 centners/ha). Implementation of works on desalinisation will allow to increase the yield of all cultivated crops

Costs on desalinisation of medium saline lands consist of costs on hydraulic engineering, organisational and economic, agrotechnical and agrochemical measures. The results of calculating the cost of works on desalinisation are presented in Table 4.

Table 4. Calculation of the cost of works on desalinisation of medium saline soils in a conventional farm (net area - 800 ha)

No	Types of work	Units of measurement	Number of units	Cost per unit, $	Total, $
	Hydrotechnical measures				
1	Conducting surface flushing (2 irrigations)	ha	800 x 2	10	16,000
	Organisational, economic and agrotechnical measures				
2	Construction of field roads	ha	4	250	1,000
3	Planting of forest belts	ha	16	300	4,800
4	Soil gypsumisation	tonna	780	10	7,800
5	Application of organic fertilisers (compost)	tonna	5,000	100	500,000
6	Application of mineral fertilisers	centner	356	2	712
7	Other costs for organisation of phytoreclamation crop rotations	ha	800	10	8,000
	Total	$	-	-	538,312
8	Coefficient that takes into account environmental factors	-	-	-	1.2
	Final total	$	-	-	645,974

On medium saline lands, a phytomeliorative crop rotation with a high content of grasses is organised, where the following crop rotation is envisaged

grasses → grasses → grasses → barley → wheat → grasses → cotton

At salinisation in average degree the increase in yield will make: on grasses - on 50 %, on cereals - on 40 %, production costs make 35-40 % from the cost of production.

The results of cash flow analysis per 1 ha are presented in Table 5.

Table 5. Cash flow analysis of works on desalinisation of medium saline lands

Calculation horizon (years)	Costs for desalinisation, $/ha	Cost of additional production, $/ha	Discount factor (interest rate 10%)	Discounted value of real money	
				Outcomes, $/ha	Incomes, $/ha
2022	115.47	-	0.91	105.1	-
2023	124.35	185.83	0.83	103.2	154.2
2024	92.86	187.66	0.75	69.6	140.7
2025	102.55	185.06	0.68	69.7	125.8
2026	112.24	186.71	0.62	69.6	115.8
2027	124.35	186.50	0.56	69.6	104.4
2028	135.66	185.62	0.51	69.2	94.7
Total	807.47	1,117.98		556.1	735.7

3.3. Desalinisation of highly saline lands, solonts, maltings, saltsands and solonchaks

At strong salinisation the following works are usually carried out: planning and repair works of drainage network; chemical melioration; land reclamation; leaching irrigation (in winter, in autumn in several steps), number of leaching - two-three per year; gypsumisation of soils; organisation of special (phytomeliorative) crop rotations with selection of phytomeliorative crops; removal or stocking of salts; electromelioration.

Calculations of expenses for desalinisation of highly saline lands have shown that income from these lands does not recoup expenses. Similar calculations were made on solontsy, maltings, which are used as pastures. As calculations have shown, the costs of their desalinisation are not currently recouped by the cost of produced products. Desalinisation of solonchaks is not effective, these lands should be conserved.

Comparison of the results obtained with the results of other researchers shows that, in general, the results obtained in this study are close to the results of other researchers.

For example, in [19] it was indicated that cultivation of annual crops on marginal saline lands caused financial losses ranging from 52 to 231 Euro/ha, even in the presence of irrigation water in the required amount. In the work [20] for recommended differentiated chemical reclamation depending on the degree of salinity. According to the author's data, the economic effect of such reclamation for medium saline lands is to obtain additional production in the amount of $63.22 per ha, and the annual economic effect is $33.58 per ha with capital costs of $206.45 per ha.

Obviously, some difference in the obtained results is explained by different conditions of research and reclamation methods.

4. Conclusions

Thus, for conditions of Syrdarya province it can be concluded that reclamation works on desalinisation of weakly and moderately saline soils should be considered economically effective, as in this case payback period of works will be 3-4 years. At the same time, desalinisation of highly saline lands and solonchaks is economically unjustified, therefore, these lands should be excluded from agricultural turnover.

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